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DEPARTMENT OF COMMERCE

UNITED STATES BUREAU OF MINES
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INFORMATION CIRCULAR

SULPHUR

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ROBERT H. RIDGWAY

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DEPARTMENT OF COMMERCE - BUREAU OF MINES

SULPHUR[1]

By Robert H. Ridgway [2]

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[2] Mining engineer, common metals division, U. S. Bureau of Mines.

INTRODUCTION

This circular outlines salient facts regarding the sulphur industry of the United States and the world. It is founded chiefly upon published information available in the literature of the subject. The Bureau of Mines has in its files additional, more detailed data upon many of the topics presented very briefly here, and will endeavor to assist the mineral industries and the public by giving further information in response to individual inquiries. It will welcome comments, criticisms, and contributions of data that may assist in making later editions of this circular more accurate, or in developing more fully the bureau's mineral files pertaining to sulphur.

Throughout this paper sulphur is used to designate crude sulphur or brimstone, not sulphur produced from pyrites or smelter gases.

PROPERTIES OF SULPHUR

Sulphur is a nonmetallic element which occurs native as a crystalline mineral. It is transparent and translucent to opaque and is highly refractive with strong bi-refringence.

Color: Bright primrose yellow, but due to impurities, often brownish, reddish, greenish or grayish.
Streak: White to yellow.
Lustre: Adamantine to resinous on crystal faces, otherwise resinous or greasy
Crystallization: Orthorhombic, of bipyramidal or tabular habit; also fibrous in spheroidal masses, stalactitic, powdery, or earthy. Molten sulphur forms long, spear-shaped, unstable, monoclinic crystals which break down into small orthorhombic crystals, the stable form.
Cleavage: Indistinct, imperfect.
Fracture: Concoidal to uneven; brittle.
Specific Gravity: Amorphous sulphur, 2.04 rhombic sulphur, 2.06; monoclinic sulphur 1.96; rhombohedral sulphur, 2.135.
Atomic Weight: 32.064.
Melting Point: 114.5 C. (238.1°F.) for rhombic sulphur; 119.25°C. (246.65°F.) for monoclinic sulphur. On melting, sulphur forms a thin, light-yellow liquid, which on being more strongly heated becomes darker and thicken; at 250 to 260°C. it is nearly black and so viscid that it does not run out when the vessel is upset; at a still higher temperature it becomes thinner again, keeping its brown color and smelting brownish red vapors.
Boiling Point: 444.55°C; has an appreciable vapor pressure at ordinary temperature, is sensibly volatile at 100°C. and in air burns at 261°C.
Conductivity: Nonconductor of heat and electricity; if rubbed, produces negative electricity.
Solubility: Insoluble in water and acids, but dissolves in carbon disulphide cold and in alcohol, ether, and light petroleum when heated.
Test: Burns readily with bluish flame, giving an irritating odor of sulphur dioxide (SO_2).

Sulphur has several allotropic modifications both crystalline and amorphous. This if boiling sulphur is suddenly quenched in water it becomes a tough, elastic material resembling India rubber, which reverts to crystalline sulphur in a few days. Also the flowers of sulphur dissolved in CS_2 leaves 5 to 6 per cent of amorphous white sulphur that is stable until heated to 100°C.

Finely divided sulphur when exposed to air and moisture undergoes slow oxidation, even at ordinary temperatures, with the formation of sulphuric acid. Similar reaction with other oxidizing agents in the presence of water permits the determination of the percentage of sulphur in many substances.

Sulphur combines with many metals when they are heated together; strips of copper, for example, burn brilliantly in sulphur vapor. Red-hot iron held agains sulphur burns in the vapor generated, with sputtering of molten iron sulphide that is formed. Under suitable conditions it also combines with most of the non-metals.

OCCURRENCE

Sulphur occurs widely and is abundantly distributed in nature in both the combined and the free state. Hundreds of minerals contain sulphur as one of their essential chemical constituents, but only a few are mined or used for sulphur, and of these few only one is used exclusively for its sulphur. This mineral is native sulphur, which as mined looks like the ordinary sulphur used in the household. A complete list of the localities containing native sulphur would include all of the volcanic regions of the world.

In its native state sulphur occurs in a pure crystalline form more commonly intermixed with earthy matter, the latter being the most important source of all native sulphur. With regard to origin, native sulphur is of two types of occurrenc Large deposits occur in sedimentary rocks and are generally the result of the reduction of gypsum. The enormous deposits of the Gulf Coast region of the United State and the deposits of Sicily are of this type.

The sulphur of the Gulf Coast region is found associated with salt dome intrusions which show many unusual features. It is probable that these domes are Permian or Carboniferous salt beds forced up through the softer sediments. The forces which caused the intrusion have been variously attributed to deposition from solution with lifting power due to crystallization and to the pressure flowage of the plastic salt. The latter theory seems to be most favored. The sulphur occurs in the limestone, gypsum, and anhydrite caprock which forms a mantle over the salt plug intrusion. There are many of these domes in the Gulf Coast region of the States of Texas and Louisiana, but only a very few contain sulphur in commercial quantities.

More commonly sulphur is found in the rocks of volcanic vents or of solfataras. Hydrogen sulphide (H_2S) is a common exhalation from volcanoes, and the reduction of this gas gives volcanic sulphur which is deposited in the tufas or other adjoining porous rock. Such deposits on a small scale may be seen incrusting fumeroles in the Roaring Mountain or associated with the sinter deposits of the Mammoth Hot Springs in Yellowstone Park. Such deposits have also been observed at many other places in the Western States— at Cuprite, Esmeralda County, Nev.; at the Rabbit Hole mines in Humboldt County, Nev.; at Sulphur Bank, Calif.; at Cove

Creek Mine, Beaver County, Utah; and at Thermopolis, Wyo. The deposits are often small and consist largely of fissure fillings. They are workable in Hokkaido and in the Island of Kyushu, Japan; in Chile; in the vicinity of Lake Rotorua, New Zealand; and in Nevada and Utah. To this type also belong the deposits of Alaska, Ecuador, Iceland, Mexico, and other volcanic regions.

The occurrence of sulphides is wide and abundant; sulphides of the metals, especially pyrite, the sulphide of iron, are scattered throughout a large part of the earths crust. Industrially, the occurrence of sulphides is of major economic importance, because of the metallic content in lead, copper zinc, and other sulphides or, in the case of pyrite, for sulphur itself. Sulphur in the form of sulphur dioxide (SO_2) is an important by-product in the smelting ores of various metals.

A list of the more important sulphides with their chemical symbols and sulphur content follows:

Mineral	Composition	Per cent sulphur
Pyrite	FeS_2	53.4
Marcasite	FeS_2	53.4
Molybdenite	MoS_2	40.0
Orpiment	As_2S_3	39.0
Pyrrhotite	$Fe_{11}S_{12}$	38.4
Pentlandite	$(FeNi)S$	36.0
Millerite	NiS	35.3
Chalcopyrite	$Cu_2Fe_2S_4$	35.0
Covellite	CuS	33.6
Sphalerite	ZnS	33.0
Enargite	Cu_3AsS_4	32.6
Stibnite	Sb_2S_3	28.6
Bornite	$Cu_5Fe\ S_4$	25.5
Tetrahedrite	$Cu_8Sb_2S_7$	23.1
Greenockite	CdS	22.3
Chalcocite	Cu_2S	20.2
Realgar	AsS	19.9
Arsenopyrite	$FeAsS$	19.7
Proustite	Ag_3AsS	19.4
Bismuthite	Bi_2S_3	18.8
Pyrargyrite	$Ag_3Sb\ S_3$	17.8
Stephanite	$Ag_5Sb\ S_4$	16.3
Polybasite	Ag_9SbS_6	15.0
Cinnabar	HgS	13.8
Galena	PbS	13.4
Argentite	Ag_2S	12.9

The possibilities of most of these minerals as sources of sulphur are very remote because of either low sulphur content or scarcity of the mineral. But sulphur in the form of sulphur dioxide is an important by-product in the smelting of ores of various metals, notably copper and zinc. The most extensive occurrences of sulphur in sulphide form are as pyrite and pyrrhotite, which are mined chiefly for their sulphur content.

A list of the countries where sulphides occur would include nearly all the countries of the world. Enormous amounts of sulphide occur in the United States Spain has large reserves of pyrite that usually contains some copper.

Although comparatively little sulphur is derived from the sulphate group, and to date it is not an important source of sulphur, occurrence of the sulphates is widespread and they have many important commercial applications other than as ores of sulphur. Combined with oxygen and bases, sulphur is found in nature as gypsum ($CaSo_4 2H_2O$), selenite ($CaSo_4 2H_2O$), and anhydrite ($CaSO_4$) as celestite ($SrSO_4$) as epsom salts ($MgSO_4 7H_2O$) kieserite ($MgSO_4 H_2O$), chalcanthite ($CuSO_4 5H_2O$), and anglesite ($P6BO_4$).

Sulphur is found in vegetable and animal tissues, in a variety of protein substances, in the hair, the nails and in horn, in the taurin of the bile, in the cystine in urine, etc. Many volatile oils for example oil of mustard, oil of garlic, etc. are composed of organic sulphur compounds to which their characteristic smell and other properties are due.

WORLD SOURCES

The principal sources of sulphur in the world to-day are the United States, Italy, and Japan, with the former by far the major factor. Other countries producing sulphur, but of minor importance, are Chile, Spain, and the United Kingdom (as a by-product of Chance-Claus process and in the purification of coal gas). Other sources of known production are Austria, Ecuador, France, Greece, China, Mexico, New Zealand, and Russia. For many years past and until 1903, 95 per cent of the worlds supply of sulphur was mined and prepared for use in Sicily. Since then, however, the United States has become the largest producer, contributing about 80 per cent of the worlds sulphur in 1929.

United States

The chief deposits from which sulphur is now obtained in the United States are in the southern part of the State of Texas near the Gulf Coast. Minor operations exist in Nevada and Utah. In 1929 more than 99 per cent of the total United States production came from mines in Texas, where three major operations contributed practically all of the sulphur mined. Two smaller mines started in 1928 but were not important producers. A new and large producing property with extensive reserves started production early in 1929. Recent activities in geophysical prospecting incident to the exploration of oil have indicated the occurrence of many previously unknown salt domes. Since the large sulphur deposits of Texas and Louisiana are located in the cap rock of such domes, the discovery of other sulphur producing domes in this district is a possibility, though all such domes are not sulphur-bearing.

The largest producing property in Texas is the Big Hill Dome of the Texas Gulf Sulphur Co. which produces upwards of 3,000 tons of sulphur a day. The other two major producers are Bryan Mound property and Hoskins Mound property operated by the Freeport Sulphur Co. Two other companies started operations in Texas during 1928 and contributed small amounts - The Palangana Dome property of the Duval-Texas Co. and the Boling Dome property of Union Sulphur Co. Early in 1929 the Texas Gulf Sulphur Co. started operations at Boling Dome, where it has developed a potential tonnage said to be the largest so far on the Gulf Coast. 3/ Sulphur deposits exist in many of the States and in Alaska and adjacent islands. Some of these deposits have been worked in the past but are not at the present time of economic importance as a source of sulphur.

Italy

Sulphur is one of the chief mineral products of Italy. With an annual production of nearly 300,000 metric tons, it is the most important sulphur-producing country in Europe and ranks second to the United States in world production. The most important Italian sulphur deposits are found on the Island of Sicily, but, sulphur occurs also on the mainland in the Emelia, The Marches, Campania, Calabria, and Sienna.

Sicily.

Sicily has produced sulphur for several hundred years, and estimates indicate that over 18,000,000 tons have been mined and extracted. At the beginning of the twentieth century most of the world's supply came from Sicily, but at present Sicily supplies less than 10 per cent. The output decreased from 500,000 tons in 1900 to 215,000 tons in 1928.

JAPAN

Since 1909 Japan has had an annual production of more than 47,000 metric tons of sulphur, most of which was exported to the United States, Australia, China, Canada, Hongkong, India. Of late the export has dwindled considerably, as Japanese production has been unable to compete in the United State with the domestic product and in 1928 was estimated at about 5,000 tons.

The Japanese deposits of sulphur are widely distributed. They are found in the volcanic districts extending from Chishima (Kurile Islands) through Hokkaido Honshu, and Kyushu down to Taiwan. Shikoku and Chosen have no sulphur mines. The most important commercial deposits are found on the Island of Hokkaido.

Spain

Deposits of sulphur associated with gypsum and impure limestones are mined in the provinces of Murcia, Almeria, and Albacete and are found in Granada, al in the southeastern part of the country. Another deposit occurs in the province of Tervel in northeastern Spain. The ore runs 30 per cent to 40 per cent sulphur but is pockety. In the Lorca region of the Murcia there is yet untouched 900,000 tons of sulphur just north of the mines previously worked in this section.

Chile

The deposits of sulphur in Chile are in the volcanic districts of that country. Deposits of excellent quality exist in Coquimbo, Atacama, Antofagasta, Tacna, and Arica. Only a small percentage is exploited, mostly from Tacna, and Antafagasta.

3/ Engineering and Mining Journal, Texas Gulf Sulphur Plans Extensive Operations: Vol. 125, Jan. 14, 1928, p. 66.

The deposits occur usually in beds of volcanic origin, but occasionally as fissure and vein fillings at or near the surface, on the flanks of old volcanoes. The workable deposits usually range from 2 to 8 feet in thickness and may reach 20 to 30 feet. The deposits occur at high altitudes, and because of the rigors of climate and rarity of the atmosphere production is difficult and all labor must be performed by native Indians accustomed to conditions.

United Kingdom

Altho very little native sulphur is found within the United Kingdom, there is a considerable production of by-product sulphur, partly from the Chance-Claus process and partly from the purification of coal gas.

The Chance-Claus process decomposes the calcium sulphide (CaS) of vat waste of the Leblanc process by means of carbon dioxide (CO_2) obtained from lime kilns, and recovers the sulphur from the sulphuretted hydrogen gas thus generated. It is difficult to obtain accurate data as to the quantity of sulphur which has been produced by this process, but estimates have stated that the minimum output has been about 35,000 tons annually, mainly manufactured in Great Britain. The sulphur recovered by the Chance-Claus process is of high degree of purity and commands a good price. The adoption of this process by the Leblanc alkali makers was very largely responsible for their being able to continue the Leblanc as opposed to the Solvay ammonia-soda process. This sourse of sulphur, however, is now rapidly becoming of less importance due to the replacement of the Leblanc caustic soda process by electrolytic methods.

The by-product sulphur recovered in the purification of coal gas is in the form of "spent oxide" and generally contains about 49 per cent sulphur. The production of spent oxide and the per cent of sulphur contained, produced in the United Kingdom for the years 1923 to 1927, is as follows:

Year	Amount (long tons)	Sulphur, per cent
1923	151,000	49.0
1924	152,000	48.6
1925	148,000	48.3
1926	128,600	48.7
1927	155,500	49.2

Russia

Sulphur beds have been known in a number of localities in Russia for many years but have not been developed. These deposits are scattered in various parts of the Union including the Mid-Volga region, the Caucasus, Turkestan, Transbaikal, Uzbekistan, Crimea, Daghestan, and Kamchatka. The most important sulphur reserve for the immediate future is the Chekur-Koyashkoe deposits at Kerch in the Crimean peninsula where minimum reserves are estimated at a half million tons in an ore containing 20 per cent sulphur. Greater deposits known as the Kara-Kum deposits exist in Turkmenistan, Turkestan, in the sandy region east of the Caspian Sea; here the existence of extensive beds of sulphur have been definitely established which are estimated to contain several million tons. It is reported that a refinery is being erected on these deposits. Large deposits of sulphur are reported to exist on the Mama River in Eastern Siberia.

Mexico

Sulphur deposits are widespread in Mexico, although at present they are of no economic importance. In the past various deposits have been worked for sulphur, but there is no production in Mexico to-day. The deposits in the crater of the volcano Popocatepetl in the State of Mexico are extensive and have long been known. A large and rich deposit occurs near Cerritos in the State of San Luis Potosi. At Venado in the same state is a smaller deposit. In Durango, at Los Conejos, near Mapimi are deposits of sulphur of possible economic importance. The deposits of Lower California are on the northern part of the western shore of the Gulf of California, notably in the vicinity of San Felipe. Other deposits occur in the States of Pueblo, Vera Cruz, Chiapas, Guerrero, Michoacan, and Oaxaco.

France

France is without known deposits of native sulphur of commercial importance, although there is a small occurrence of sulphur in the vicinity of Baibaux and a small quantity of sulphur-bearing marl is mined in the departments of Bouches-du-Rhone and Vaucluse. The latter is found in a very impure state, mixed with mud in the sulphur marshes of these regions. The production amounts to about 1,400 metric tons annually.

Miscellaneous

Sulphur deposits also exist in Poland in the vicinity of Krakow and Sywosywice; in Yugoslavia in the old province of Croatia near Radoboj; in Persia near Misjed-i-Sukinam and near Semnan in the province of Semnan; in Greece on the island of Melos; in Attica on the Peloponessus and in several islands in the Aegean; in the Shansi province in China; in Cyprus in the mines at Skouriotissa; on the island of Vanua Lava in the New Hebrides; in Ecuador; in Peru; in Abyssinia and at White Island, New Zealand.

CHIEF DEPOSITS AND TECHNOLOGY OF PRODUCTION EMPLOYED

UNITED STATES

The chief producing deposits in the United States are those in Texas, operated by the Texas Gulf Sulphur Co. and the Freeport Sulphur Co. The Duval-Texas Sulphur Co. and Union Sulphur Co. are much smaller producers operating in the same field. The location of these deposits are shown on map in Figure 1. The Humboldt Sulphur Co. is operating in a small way on a deposit in Nevada. Another small deposit is being operated in Utah by the Utah Sulphur Industries.

Texas Gulf Sulphur Co.

The Texas Gulf Sulphur Co. is mining sulphur at Big Hill Dome and at Boling Dome.

Big Hill Dome:

Location.- The Big Hill Sulphur deposit of the Texas Gulf Sulphur Co. is located at Gulf, Matagorda County, Tex. It lies about midway on the coast line of

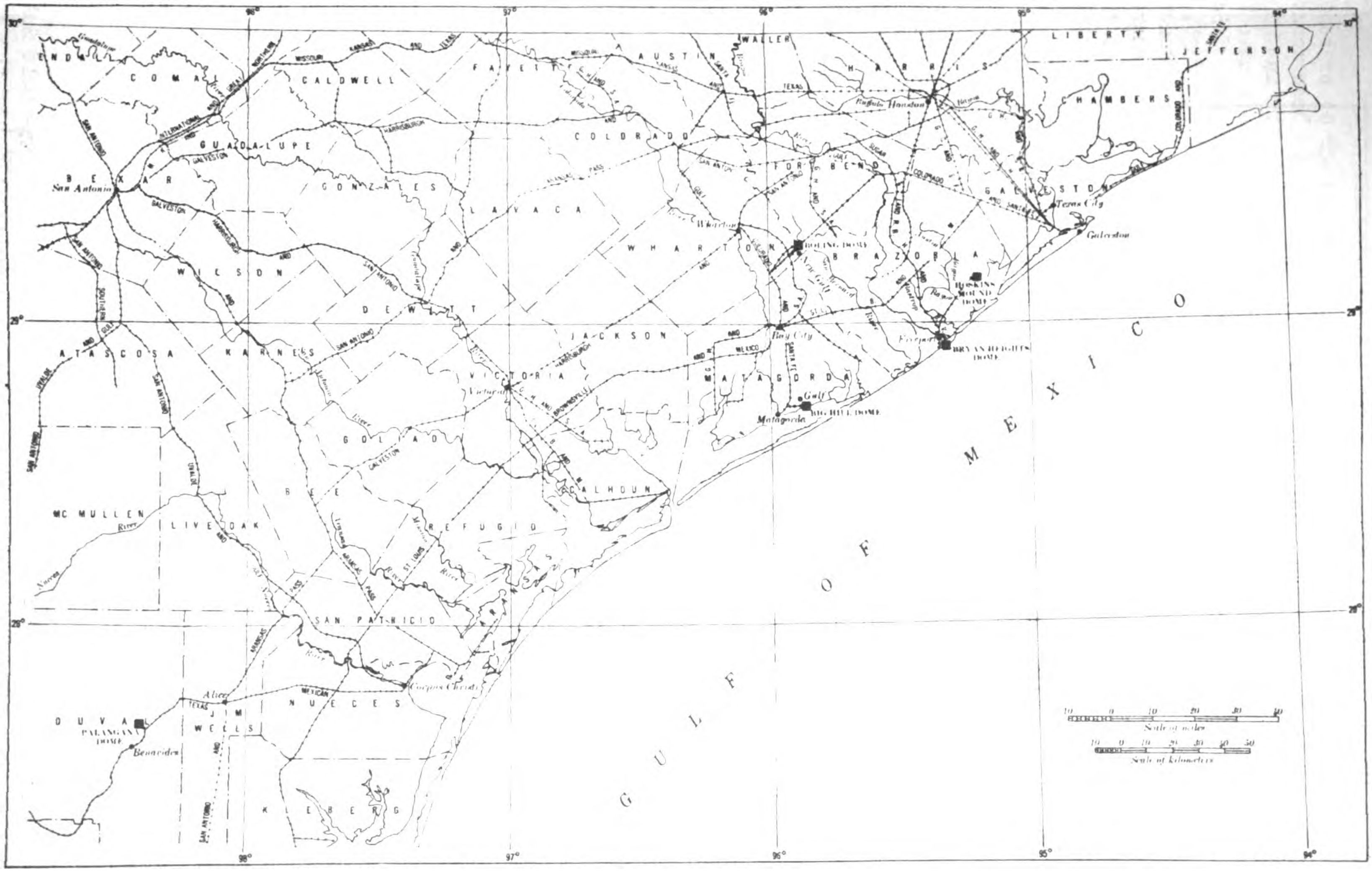

Figure 1. – Map of Gulf coast region of Texas

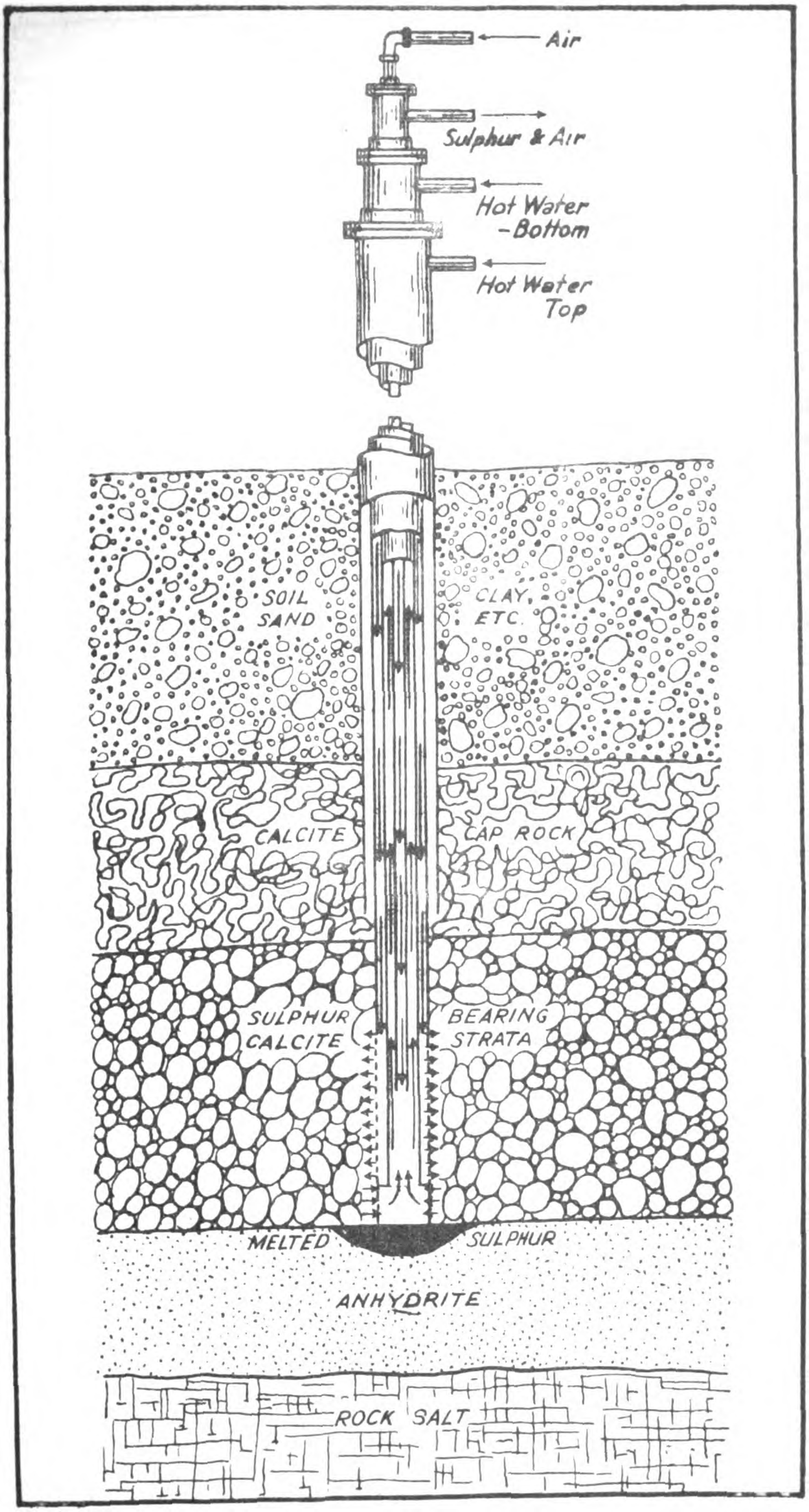

Figure 2.—Diagram of method of sulphur extraction

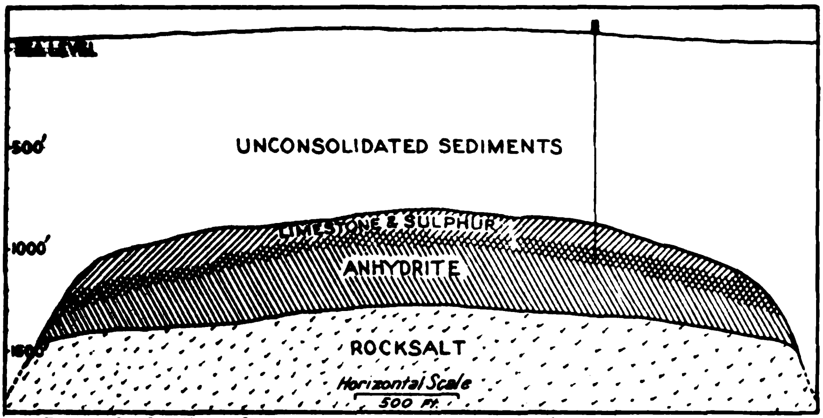

Figure 3.-Section of Big Hill Salt Dome, Matagorda County, Texas

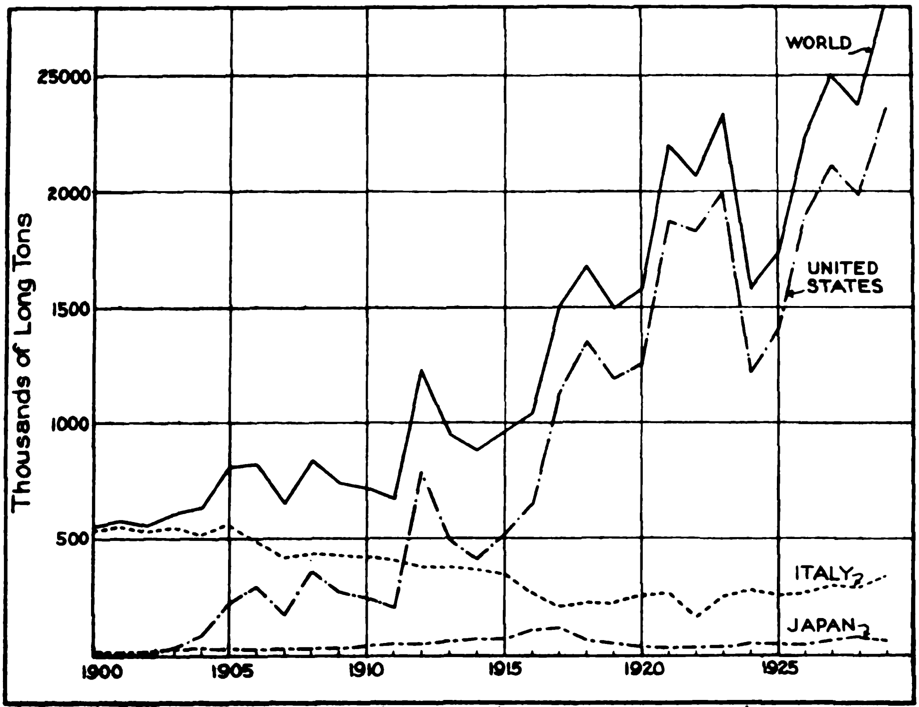

Figure 4.-Production of Sulphur in the World and in the main producing countries 1900 to 1928

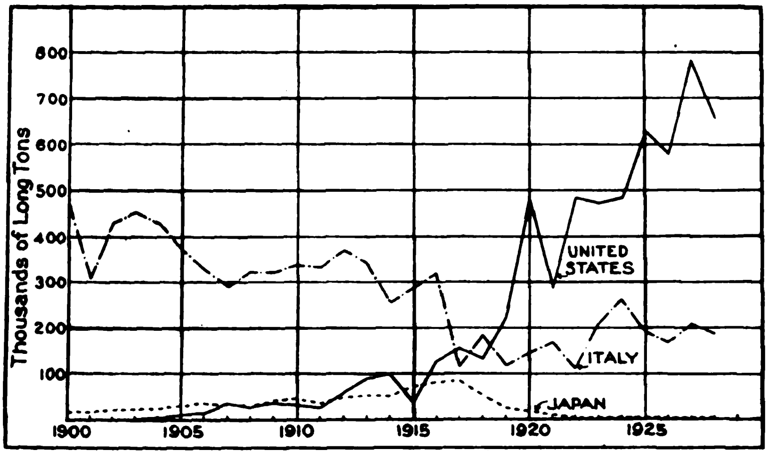

Figure 5.-Exports of Sulphur from the main exporting countries 1900 to 1928

the county and 1 mile from the shore of Matagorda Bay; 20 miles southeast of Bay City, Tex., and 80 miles southwest of Galveston, Tex.

Production.- Production from this property started in 1919 and had amount to something in excess of 7,000,000 long tons of sulphur at the end of 1928. At present this property is the largest producer of sulphur in the world, yielding ove 1,000,000 tons of sulphur annually.

Character of the deposit.- Like other sulphur deposits in this district, that at Big Hill occurs in the cap rock overlying a salt dome. The dome has a distinct salt-dome mound, a salt core roughly elliptical in shape with an east-west axis of about 4,000 feet and a north-south axis somewhat longer. This rises into Tertiary sediments, of which there is a thick cap above the salt. The main features of the dome are illustrated in Figure 3. The cap rock which contains the extensive and important deposits of sulphur is composed of (1) a barren cap of limestone above (2) the sulphur barren zone chiefly of limestone which grades below into (3) a thick deposit of anhydrite barren of sulphur.

The sulphur occurs in massive form in layers; as the filling of irregularly shaped cavities which sometimes are several feet in diameter; in little bunches, specks, and veinlets; and in beautiful orthorombic crystals lining vugs. The color of the sulphur ranges from a bright canary-yellow in both the crystalline and massive forms to dark brownish and greenish tints in the massive form. It is all extremely pure, and color is no indication of any appreciable percentage of foreign matter.

The sulphur is of later age than that of the anhydrite. It varies in thickness from 60 to 90 feet and occurs in a zone immediately below the limestone at depths of 870 to 1,215 feet. The sulphur content of this zone varies from 20 to 40 per cent. Unconsolidated muds and sands lie above the limestone cap. It has been estimated that over 11,000,000 tons of sulphur are available in this deposit.

History.- The presence of sulphur in this locality was revealed in 1901 by drillings for oil. In 1909 drilling of the dome for sulphur was undertaken; it resulted in the formation of the Gulf Sulphur Co., succeeded by the Texas Gulf Sulphur Co. in 1918. The Government furthered the development and equipment of the property because of the war demand for sulphuric acid and the possible shortage of sulphur. Construction of the plant was commenced in July, 1918. The first sulphur was brought to the surface March 19, 1919, and at the end of 1921 over a million tons of sulphur had been produced.

Operations.- The sulphur is mined by a variation of the Frasch process, the basic principle of which is the injection of large volumes of superheated water into the formations for the liquefaction of sulphur; this permits the pumping of liquid sulphur to the surface. The process was developed by Dr. Frasch from 1890 to 1903 on a similar deposit in Calcasieu Parish, La., which ceased to operate, due to exhaustion, in December, 1924, after producing some 10,000,000 tons of sulphur.

Ordinary oil-well equipment is used to bore holes to the bottom of the sulphur-bearing strata. Concentric pipes varying in size from 10 inches to 1 inch are placed in the holes. A 10 inch or an 8 inch casing extends to and rests upon the cap rock. Inside this casing a pipe of smaller diameter passes below the lower end of the casing, through the sulphur-bearing stratum, and rests in the upper portion of the barren anhydrite. A still smaller pipe passes through the second so that an annular space exists between the two; it extends nearly to the bottom of the sulphur-bearing rock and rests on a collar which seals the annular space between the second and third pipes. Finally, a 1 inch air pipe, inside all the others, extends to a depth slightly above the collar mentioned above. The second pipe is perforated at two different levels, one above and the other below the annular collar. The upper set of perforations permit escape of the hot water while the molten sulphur enters the system through the lower perforations. The well equipment is illustrated in Figure 2.

For operation of the well, hot water is passed down the annular space between the second and third pipes. It discharges through the perforations into the porous formation near the foot of the well. The region about the well through which this water circulates is raised to a temperature above the melting point of sulphur. Molten sulphur, being heavier than the water, makes its way downward to form a pool around the base of the well where it enters through the lower perforations and rises in the space between the third and fourth pipes. The height to which the sulphur rises between the pipes is a consequence of its specific gravity and the pressure in the porous formation established by the force of the water produced by the pumps in the power plant and required to secure its entrance into the deposit. The height may be one-half or two-thirds of the depth of the well. Compressed air, released at the bottom of the central 1 inch pipe, rises and mixes in the sulphur column, the weight of which is reduced by aerification thus producing an air lift that raises the sulphur to the surface. At the surface the sulphur from the wells is collected in heated sumps at pumping stations from which it is pumped through well-insulated pipes into large wooden vats. The wooden vat walls are built up slowly and are kept only a few inches higher than the sulphur. When the vat is complete the wooden walls are removed. The sulphur is in a solid state and requires no support. The vats vary in size and are as much as 800 feet long, 200 feet wide, and 50 feet high. They often contain over half a million tons. The block of sulphur is drilled, broken down by blasting, and loaded into cars by a locomotive crane. Shipments to the Gulf Coast are made in open cars whereas shipments inland are made in box cars. Box cars must be used behind coal-burning locomotives because of the fire hazard.

In the operation of this process large amounts of water and fuel are necessary. The fuel used at this plant is natural gas which has replaced the crude oil originally used, though the crude-oil equipment is still held in reserve. The water is brought in from the Colorado river by a canal 25 miles long. Feed water treatment is effected by the lime-soda process. The water for mining sulphur is heated in mine water heaters by steam which is generated in a series of 700 horsepower water-tube boilers. The water heated to about 330°F. is sent underground at 100 pounds pressure. The large amounts of water pumped into the ground collects in the sulphur formation because of the impervious nature of the material above and below. The cooled water near the edge of the formation is drawn off through bleed wells practically as fast as hot water is forced down elsewhere. The bleed water is conducted through heat exchangers countercurrently to the feed water for the mine water heaters, in order to recover a good deal of the heat in the bleed water. The bleed water is not used over again in the heaters or boilers because of the impurities it has collected in its passage through the underground strata; it is wasted into the Gulf.

Future outlook.- The estimates of the amount of sulphur in Big Hill Mound have varied from 8,000,000 to 11,000,000 tons. Production through 1929 has been over 8,000,000 tons. While this would indicate that the property is nearing depletion, it is believed that a considerable reserve remains yet to be mined.

Boling Dome:

Location.- Boling Dome is located in the southeastern part of Wharton County, Tex., about 60 miles west of Galveston and 50 miles southwest of Houston.

Discovery of sulphur in quantity on Boling Dome was made in March, 1927.

Production.- Production from the property was started in March, 1929, and in the first six months amounted to upwards of 150,000 tons of sulphur.

Character of the deposit.- Boling Dome lies in a wooded tract adjacent to the San Bernard River. The dome, which is a typical salt dome deposit, is probably the largest ever found, being over 4 miles long in a north and south direction and about 3 miles wide, as determined by geophysical methods. The data obtained by an extensive drilling campaign indicates that the deposit contains several times as much sulphur as the deposit in the Big Hill Dome, which has produced over 8,000,000 tons to date. The approximate edges of the deposit have been determined as closely as possible and the sulphur in the cap rock is found in the shape of a half moon. It lies at depths of about 700 feet and deeper.

Operations.- It is said that upwards of $10,000,000 has been spent on the installation of a plant for mining the sulphur by the Frasch method.

Water for the plant is obtained from the San Bernard River. On the river bank, a pumping station of four units, each of 10,000 gallons per minute capacity and capable of working against a 65-foot head, has been erected. The capacity of the pumping plant is actually much in excess of plant requirements, but is large enough to take advantage of the seasonal variation in water supply by storing surplus water in a reservoir. A 262 acre reservoir capable of holding 750,000,000 gallons has been provided. Part of the water required for operation is converted into steam, which is then used to superheat the remaining water for extraction of the sulphur and for supplying the steam lines used to keep the sulphur flowing in a molten state until it can be delivered to the vats for storage. All water is treated chemically by the Cochrane hot water process to remove scale-forming impurities.

To generate the large amount of steam required to heat the water a power house containing five Babcock & Wilcox type water tube boilers has been erected. The boilers have a rating of 1,500 horsepower but may be operated continuously at 200 per cent of rating. Four boilers will be in operation continuously, one being held in reserve. In addition to the boilers, the power house is equipped with the necessary hot water heaters, air compressors, pumps, and electric generators required for plant and townsite purposes.

Natural gas is available and is used, but to guard against the possibility of any temporary failure in the supply of natural gas, the boiler plant is equipped so that fuel oil may be burned if desired. To store the supply of fuel oil requisite for emergency operation, a tank of 80,000 barrels capacity surrounded by a levee has been provided. The boiler installation is also designed to be easily adapted to the use of powdered lignite.

The bleed water which is contaminated with hydrogen sulphide and other impurities taken into solution is aerated and treated for their removal. The water is then conducted through a ditch 20 miles long to tidewater.

Though this property has been producing sulphur since March, 1929, no shipments of sulphur have been made as yet.

Future outlook.- Early in 1930, contracts were let for new additions to the plant which will double the original boiler capacity. The additions also include extensions to the water-treating plant, and water-heating equipment and pumps, and the construction of a second stack.

It is to be expected that this property, with its immense reserves, will soon become a major producer.

Freeport Sulphur Co.

The Freeport Sulphur Co. is the operating subsidiary of the Freeport Texas Co. It operates at Bryan Mound and at Hoskins Mound and is the second largest sulphur producing company in the world.

Bryan Mound:

Location.- The Bryan Heights Salt dome is located in the southern part of Brazoria County, Tex., 1 mile from the Gulf Coast and 3 miles south of Freeport, Tex. about 40 miles southwest of Galveston, and 60 miles south of Houston.

Production.- The Freeport Sulphur Co. started producing from this property in 1912 but owing to slight defects in the machinery the work ceased for some months. During 1914 or 1915 work was resumed with a greatly enlarged plant. To date, the property has produced over 4,000,000 tons of sulphur.

Character of the deposit.- Bryan Mound is one of the structural domes characteristic of the Mississippi embayment which is evidenced on the surface by an actual mound. The cap rock, roughly circular in shape, with diameter of about 1 mile, contains the valuable deposit of sulphur. The sulphur occurs in pockets and cavities and as streaks impregnating gypsum in a formation including limestone and dolomite in which gypsum predominates. The sulphur-bearing formation has a thickness of about 150 feet, it is overlain by 700 to 900 feet of gravel, "gumbo," and "cap rock." Its bottom is usually 900 to 1,000 feet below the surface. Below it there is gypsum and rock salt. Kirby Thomas[4] examined 174 feet of sulphur-bearing core from well No. 4, Gulf Development Co., beginning at a depth of 818 feet. This consisted of limestone, gypsum, and sulphur. He estimated that in this section there were 35 feet having less than 10 per cent sulphur, 85 feet from 10 to 50 per cent sulphur, 54 feet missing due to friability. One-third of the 120 feet of core available was estimated to contain 20 per cent sulphur or better. Beneath this there followed in depth: Lime rock and pyrite, 8 feet; gypsum, 37 feet; lime rock and pyrite, 5 feet; sandstone, 28 feet; and salt, 19 feet. The original estimate gave reserves of 17,000,000 tons of sulphur.

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[4] Phalen, W. C., Sulphur: Mineral Resources of the United States, 1912, Part II, U. S. Geol. Survey, 1913, p. 935.

History.- Attention was first called to Bryan Mound by S. F. Peckham, in a petroleum report of the Tenth Census, 1880. During the oil excitement of the year 1901, the J. M. Guffey Petroleum Co. obtained a number of leases around and on the mound and commenced drilling. The field was considered valueless for oil and was abandoned. Other parties acquired the leases subsequently and attempted to drill for oil, but in each case the operations proved fruitless. During the course of this work the drill is reported to have passed through large deposits of lime and gypsum showing considerable quantities of sulphur. These materials were encountered between 700 and 900 feet beneath the surface.

In 1906 a company was incorporated to prospect Bryan Mound for sulphur. It was asserted that sulphur had been found in every one of 27 test holes put down, and that about 300 acres had been proved to be sulphur-bearing to a workable degree Difficulties were encountered, however, in obtaining a right to mine under the Fra Frasch process patents then in force.

About 1912 the property passed into the hands of Freeport Sulphur Co., and a plant was installed at a cost of $200,000. During the early part of December 1912, sulphur was brought up for a few days, but owing to slight defects in the machinery, work ceased for some months. During 1914 or 1915 work was resumed with a greatly enlarged plant. Bryan Mound has been a heavy producer ever since.

Operations.- The process of extraction is similar to that described under Big Hill Mound of Texas-Gulf Sulphur Co., by which the sulphur is melted underground through the introduction of hot water into the sulphur-bearing formations. Natural gas is used as fuel to heat the boilers which generate the steam for heating the mine water and for generating the power necessary to run the plant. Oil was previously used and that equipment is now held in reserve. The large amounts of water necessary for the mining operations are brought in from the Brazos river in a canal. The water is treated for hardness. Heat exchangers transfer the heat from the bleed water from the formations to the feed water to mine water heaters.

The character of the formations at this property make it necessary to resort to mudding operations in order to obtain a workable efficiency from the heated mine water. As the sulphur is removed from the formations huge cavities remain because the character of the cap rock is such as to not permit any great subsidence of the unconsolidated formations from above into these cavities. As a result, the heated mine water escapes through these channels without circulating through the formation, In order to combat this, mud is dredged at the surface, put through classifiers and machines for removing lumps and large pieces of material likely to plug pipes, and the sludge is finally pumped underground. Its filling of open cavities causes a more efficient circulation of the hot mine water.

The sulphur is run into vats as previously described and then loaded into cars, It is taken either to Freeport, Tex., or to Texas City, Tex. for transfer into ships.

About 1,000 tons of sulphur per day are being mined from this mound at present.

Future outlook.- While the production from this property to date has been about 4,000,000 tons and previous estimates have indicated 17,000,000 tons, it is not generally believed that this property will attain a total production anything like its original estimated content of sulphur. More recent estimates give Bryan Mound a remaining reserve of 1,256,779, tons.

Hoskins Mound:

Location.- Hoskins Mound is in the southeast part of Brazoria County, Tex., about 14 miles northeast of Bryan Mound and about 25 miles west of Galveston, Tex.

Production.- This property did not come into production until 1923, but since then its output has averaged nearly 300,000 tons per year. At present it is one of the most important producers of sulphur in the world, being surpassed only by the Big Hill Dome of Texas Gulf Sulphur Co.

Character of Deposit.- The character of the deposit closely resembles that of Bryan Mound, previously described.

History.- Between 1900 to 1905 oil prospecting disclosed the presence of rich sulphur strata at Hoskins Mound, the sulphur ranging in depth from 800 to 1,500 feet. Before operations started, drilling had shown a minimum of 6,000,000 tons of recoverable sulphur, but further drilling raised the estimate to 11,000,000 tons of sulphur with only about half of the dome area drilled.

Operations.- Sulphur is produced at Hoskins Mound by a variation of the Frasch process, mudding operations similar to those described at Bryan Mound are used to fill the underground cavities. The main source of water supply is Austin Bayou about 5 miles from the mound. Large reservoirs afford an adequate reserve of water. The water is treated for the removal of scale-forming and corrosive substances. The production at present ranges from 1,000 tons to 1,500 tons per day.

Future outlook.- This is a comparatively new property with extensive reserves, and it is probable that it will continue to be a major sulphur producer for some time.

The Duval-Texas Sulphur Co.

The Duval Texas Sulphur Co. is a new operator and is mining sulphur at Palangana Dome.

Palangana Dome:

Location.- Palangana dome is in the lower Gulf Coast region and is more than 100 miles west and south of the deposits in the vicinity of Houston, Tex.

It is 6 miles from Benavides, Tex., in the east central part of Duval County, or about 110 miles due south of San Antonio, and about halfway between Laredo, and Corpus Christi, Tex.

Production.- Production of sulphur from this dome started in November, 1928, and to date has been small. More recent additions to the plant have increased its capacity. The production in the later part of 1929 amounted to about 150 tons per day.

Character of the deposit.- Palangana has the characteristic structure of a salt dome. The salt core is approximately circular in outline with a diameter of 1,100 feet; it has a flat top covered by a cap rock which extends well down the flanks dipping steeply away from the salt core. A generalized section through the cap rock is as follows:

	Feet
Limestone, calcite, clay and shale	5-20
Limestone, calcite, clay, shale and sulphur	3-25
Gypsum	100
Anhydrite	300

The sulphur-bearing stratum is generally found at depths between 400 and 500 feet; it is thin but rich.

Unlike most other salt domes of the Gulf Coast region, the surficial expression of this dome is a circular ring of low hills surrounding a central basin. The diameter of the floor of the basin is 8,000 feet, and the diameter of the ring of hills, which rise 50 to 80 feet above the floor of the basin, is 15,000 feet.

Little is known of the reserves and resources of this property and no drilling has been done on the flanks of the dome, but it has been estimated recently that this property contains between 500,000 and 1,000,000 tons of sulphur.

History.- Palangana dome was discovered in 1916 by the Empire Gas and Fuel Co. during a search for oil. In 1923 a shallow test well on top of the dome disclosed considerable sulphur. In 1924 the Texas Gulf Sulphur Co. drilled 25 tests and the Union Sulphur Co. 3 tests for sulphur.

Operations.- The Frasch method is used with certain variations due to peculiar conditions. The water for their operations is obtained from wells in the vicinity and stored in tanks holding only 24 hours supply. The nature of the ground will not permit the large open reservoirs which are characteristic of other sulphur operations. Gas is burned under the boilers after having been used expansively in the pumps to supply water to the plant. The bleed water is pumped over the rim of hills into a pond where seepage and evaporation are about equal to the bleed water pumped into the pond. The plant is connected by a spur track to the Texas-Mexican Railway Co.

Future outlook.- This mine is a relatively small operation, and is more or less in the experimental stage at present. As the property has not been thoroughly drilled the extent of the deposit is not known. The present plant and equipment will not permit extensive production.

Union Sulphur Co.

At one time the Union Sulphur Co. was the largest producer of sulphur in the world, but recently it has been of minor importance due to exhaustion of its sulphur salt dome in Calcasieu Parish, La. It was at this property that Dr. Hermann Frasch worked out his method of mining in the decade ending 1903. This property yielded nearly 10,000,000 tons of sulphur before exhaustion.

In 1928 the Union Sulphur Co. started production at a small tract on Boling Dome. No shipments have been made, and production to date has been small. Recently the company was involved in litigation with the Texas Gulf Sulphur Co. and failed in an endeavor to cancel leases to land it had given to the Texas Gulf Sulphur Co. on Boling Dome.

ITALY

The most important sulphur deposits in Italy are found on the Island of Sicily, but, deposits of economic importance are found also on the mainland, chiefly in the Romagna.

SICILY

Location.- The Sicilian sulphur bearing belt, averaging 85 miles in width, extends from Mount Etna on the east to Gergenti on the west, a distance of more than 100 miles. The center of the industry is at Caltanisetta.

Production.- Sicily produces annually over 200,000 tons of sulphur and is the second most important sulphur-producing district in the world.

Character of the Deposits.- The sulphur of Sicily is found chiefly in an argillaceous limestone associated with gypsum and bituminous marl. Its structure is coarsely crystalline but usually compact. The sulphur-bearing rocks occur in the form of immense lenses rather than as extensive beds. The lenses are of variable thickness and richness. Within the sulphur-bearing layer proper the sulphur occurs either in the form of irregular incrustations and small pockets, intimately mixed with limestone, or in thin bands (1 to 2 millimeters thick) interlaminated with country rock. The color of the sulphur is usually brown or brownish gray, and occasionally is light yellow. The darker color is usually due to the intimate mixture of bituminous substances. The minerals associated with the crystalline sulphur are chiefly celestite, aragonite, calcite, and gypsum.

While most of the earlier theories laid unusual stress upon the direct influence of volcanism on the deposition of sulphur, it is now universally accepted that the sulphur is a result of the oxidation of H_2S, and this has caused the theor of bacterial reduction to be given serious consideration.

The sulphur content of the deposits in the western part is not as great a toward the central part. Richer deposits generally have 15 to 20 per cent sulphur, a few as much as 50 per cent, and in places 80 to 90 per cent material is found. Workable deposits carrying up to 40 per cent sulphur are considered as limestone impregnated with sulphur and above 40 per cent as brimstone (more or less pure sulphu

The mines are concentrated in groups where richer ore renders the expense of extraction least. Individual beds vary in thickness from 3 to as much as 100 feet, but average about 10 feet. Most of the mines are not deep, though a number o them are being worked to depths of 800 to 1,000 feet or more.

The reserves of sulphur in Sicily are still very extensive.

History.- Sulphur has been produced commercially in Sicily for several hundred years. In 1838 a monopoly of the Sicilian export trade in sulphur was placed in the hands of a French company (M.M. Taix et Cie, Marseille), which nearly tripled the price of sulphur. This increase in price forced manufacturers of sulphuric acid to use iron pyrites as their source of sulphur. As a result the Sicilian producers lost all of this trade, which they have never been able to regain. Then followed the withdrawal of the French monopoly with the subsequent reestablishment of the old price or about $25 per ton of sulphur.

In 1890 there was developed in England the Chance-Claus process for the recovery of sulphur from the alkali waste of the Le Blanc soda process. Advantage was taken of the possibilities of this process to cause internal competition among Sicilian producers, which resulted in a drop in the price of sulphur to $11, out of which came an export tax of $1.95 per ton. This state of affairs continued until 1896, and the Sicilian laborers were on the verge of starvation and revolution. British and Sicilian interests then combined to form the Anglo-Sicilian Sulphur Co. whose control of the industry resulted in fair and satisfactory prices to both consumer and producer, and a period of prosperity succeeded in Sicily.

The successful application of the Frasch process to sulphur deposits in the United States gave another setback to the Sicilian industry. United States sulphur soon supplied the extensive American market and invaded that of Europe. The Italian Government therefore exempted sulphur from taxation in 1905 and financed the Consorzio Obligatorio per L'Industria Solfifero Siciliano of Palermo (Compulsory Consortium for the Sicilian Sulphur Industry, commonly referred to as the Consorzio or Consortium). It replaced the Anglo-Sicilian Co., and was charged with the sale and regulation of the production of Sicilian sulphur. The rights of this Government syndicate expired in 1918 but was extended for another 12 years.

In 1907 an agreement between the Union Sulphur Co. and the Sicilian industry assigned the United States market to the former and the Mediterranean market to the latter, but two new American producers found themselves able to sell sulphur in Sicily more cheaply than it could be produced there. Decreased Sicilian sales of sulphur led to an agreement between the American and Sicilian sulphur producers in the Spring of 1923. The agreement, which applied only to unrefined sulphur, assigns North America to the American producers, Italy to the Sicilian producers, and the remainder of the World proportionately between the two, with the provision that Sicily may sell to any country a maximum of 65,000 tons for the manufacture of sulphuric acid. The agreement permits Sicily to export annually a total of 210,000 tons, including the 65,000 tons for sulphuric acid manufacture. It was to be valid until September 30, 1926, but it is understood that it continues in effect. Provision was made that dissolution may not occur during the sulphur selling season. Recently it was announced that the cabinet of the Italian Government has approved a bill extending the Sicilian sulphur consortion to 1940.

Probably the most important event in the recent history of the Sicilian sulphur industry was the agreement reached by the sulphur Consortium and the Society of Sicilian Sulphur Refineries in 1925. The terms of this agreement have been summed up as follows:

> The Consortium is to share equally with the refineries in the net profits derived from the sale of the refined product, but is exempt from contributing anything in the event of any loss from that end of the business. The Consortium does not contribute any capital and therefore is not concerned with the kinds of refined sulphur produced, but is indirectly connected with the selling end of these refined products and shares in the profits. The Consortium has full power relative to the movement of crude sulphur, but is bound to sell only to the refineries belonging to the Society of Sicilian Sulphur Refineries, and the latter are bound to refine only sulphur furnished to the Consortium. The crude sulphur is to be paid for according to prices published by the Consortium and not, as previously, on a basis of the cost of production at the mine, which was always varied according to the location. The principal advantages to the Consortium are, therefore, an exemption from assessment in case of loss and an equal share in any net profits resulting from the refining operations. The advantages gained on the part of the refiners are those emanating from closer cooperating with the extractive end of the industry and a more certain basis upon which to work in carrying on refining.

It was evident that Sicily, with its antiquated methods of production, could not meet United States competition, and it was thought that the industry could not be placed on a paying basis unless the heavy burden of the "Estaglio" system of operation was removed. Under the "Estaglio" or royalty mode of operating the sulphur mines the owners obtained royalties from their concessionaires varying from 30 to 70 per cent of the total annual yield of the mines. These royalties were paid in kind. This division of the profits did not tend toward increased production. Accordingly, in 1927, a law was enacted known as the Beluzzo law. The operation of the law implies a complete reversal of the existing system and contains two interesting innovations which affect not only the sulphur industry but property rights in general. Under the old mining legislation the owner of the surface also owned the subsoil. In Sicily the landowners rarely worked the mines themselves, but leased the subsoil to the mining companies and collected huge royalties. Vast tracts were held by absentee landlords, who contributed practically nothing to the economic life of the country but realized large incomes from their mining royalties. The new law practically dispossesses these landowners of their subsoil rights. Although the Government has not issued any decree or law formally attributing the subsoil to the State, Beluzzo in his report stated that the new mining legislation is based on the principle that the subsoil forms part of the State demesne. That is, mining concessions may now be given only by the Government. The owner of the land is preferred as a lessee if he has the means and capacity to operate the mine, otherwise the Government leases the property to whom it sees fit. The owner of the land will no longer receive royalties or any compensation beyond the actual value of the surface; nor will the Government collect royalties from mine operators. A nominal fee of 5 lire per hectare is all that the State receives. Mining concessions may be given in perpetuity and may be inherited. Existing concessions are allowed to stand until the expiration of the contract, and therefore the full effect of the new legislation will not be felt for a year or two.

In the meantime, however, the royalty percentage payable on existing contracts was in every case reduced by one-third.

The present tendency in the Sicilian sulphur industry is to close down the smaller mines. During 1926-1927, 293 mines were worked, but during 1927-1928 only 247 mines were worked. Smaller mines using antiquated and uneconomical methods are being weeded out. The greater part of the remainder will consolidated in the hands of larger and well-equipped mining companies. Improved organization of the industry is resulting in reduced production costs and improved quality. The immediate result of the new system will probably be a falling off of production during the transition period. This declining tendency in the Sicilian sulphur industry is reflected also in the smaller number of people engaged in it, which at present is only 10,000 as compared with 40,000 a few years ago; this is partly attributed to the use of electricity and modern machinery at the mines.

Operations.- The methods of mining Sicilian sulphur are very simple. As the island is mountainous, tunneling into the hillsides is common. Most of the ore, however, is mined through shafts, both inclined and vertical. Some properties have modern hoisting machinery and trams. In others steps are hewn in the rock of the shaft and the sulphur ore is carried to the surface in baskets. Until declared illegal, a large number of boys were used in most of the smaller mines to carry the sulphur to the surface. Explosives are used in many of the mines, but the utmost caution must be taken to prevent fire. Timber supports are never used in these mines.

Sulphur is extracted from the ore by (1) burning part of the sulphur in mounds called calcaroni (2) by burning part of the sulphur in Gill regenerative kilns (3) and by means of retorts heated with superheated steam. In the calcaroni system sulphur ore containing not less than 15 per cent sulphur is built into a mound, 9 feet high, over a circular floor about 60 feet in diameter. The ore is covered with fine residue material from a previous mound. Fuel is used to start combustion, but the sulphur is melted partly by the heat of its own burning. Beneath the heap, the sloping floor has compartments in which the fused sulphur collects and solidifies into bricks weighing about 100 pounds each. A recovery of about 60 per cent is possible, but the escaping sulphurous gases case destruction to the vegetation in the district.

Since 1880 the Calcaroni system has been more and more replaced by the cell ovens or regenerative furnace introduced by Robert Gill. The Gill Kiln consist of a series of circular chambers connected by a system of flues. The cells are worked together in series; usually four or six cells form an angular or ring-shaped battery. Each cell contains from 5 to 30 meters of ore. The first cell holds a fresh charge, and the last the residue of a former fusion. Air enters the chamber containing the residue, becoming thus preheated; it enters through the connecting flue into the next kiln, where some sulphur is burned and the heat evolved melts most of the remainder. The hot gases then pass through a third and sometimes a fourth kiln heating the charges in those chambers and condensing any sulphur. The gases heavily charged with sulphur are not lost as in the calcaroni method; the yield is much larger; the time shorter (three or four days for each cell); and as the quantity of smoke is much less the work can be continued almost all the year round without danger to crops. Other advantages are those accruing from easy regulation of combustion and the operation of a continuous process. The Gill kiln, with further improvements and modification under the name of Salfilippo, has increased the yield of sulphur from one to as much as 80 per cent.

By employment of superheated steam the recovery has been increased in the Romagna to 90 per cent, but the great scarcity of fuel has prevented its extended application in Sicily. The process is simple. The ore is brought from the mine in 1 ton cars with perforated bottoms and placed in a boiler. Steam under a pressure of about 60 pounds per square inch is let in, which causes the sulphur to melt and drop through the perforations in the bottom of the car. It collects in the bottom of the boiler and is drawn off. In 1927 61 per cent of the sulphur produced in Italy was won from the ores by the Gill furnace, 30 per cent by the Calcaroni process and 8 per cent by steam recovery methods.

The sulphur as first obtained by simple melting out from the ore is far from pure and quite useless for many purposes, but most of the impurities, amounting to 3 or 4 per cent, may be removed by distillation or sublimation.

Future outlook.- Sicily has extensive ore reserves, and with the use of improved mining methods and modern mining machinery its costs should be materially lowered. Lower royalties and the consolidation of the smaller properties may effect further economies so that in the future the production from Sicily is likely to increase.

ITALY - MAINLAND

Most of the sulphur produced in Continental Italy comes from the mining district of Bologna in the provinces of Emilia and The Marches. Production from this district is now estimated at 100,000 tons.

The sulphur deposits of The Marches and Emilia are very similar to the Sicilian deposits as to their occurrence, origin, and mineral contents. The methods of mining and extraction of sulphur from the ores are also similar to those used in Sicily. In this district superheated steam has been used and found very effective in extracting sulphur from ore.

The mining district of Napoli in Campania produces the remaining continental production. Most of this production is not extracted from the ore but is ground and sold as "machinato" sulphur or ground crude sulphur rock.

The production of sulphur from the mainland of Italy is becoming more and more important.

JAPAN

Although most of the Islands in the Japanese empire have deposits of sulphur, the commercial deposits are largely located in Hokkaido, which furnishes about 85 per cent of the production.

Production

Japan produced 59,660 metric tons of sulphur in 1929 and has been the third most important producer of sulphur in the world for the last quarter century.

Character of Deposits

Occurrences of sulphur in Japan are of the solfatara type; some of them are beds formed in old solfatara lakes and have more or less circular boundaries. The thickness of the deposits sometimes exceed 100 feet, but their horizontal extensions are comparatively small. The occurrence of the sulphur is not uniform in the various districts. In some localities large masses of sulphur are found covered with volcanic lava, in others it occurs mixed with clay. At Iwaoto there is a deposit of precipitated sulphur and another consisting of intrusions of fused sulphur in a sandy bed. The deposit at Horobetsu shows a continuous vein of pure sulphur in the form of irregular granules.

Only the richer ore, containing 30 to 60 per cent of sulphur, is mined; it is refined up to 99 per cent or better.

The sulphur is mined both by open-cut and underground mining methods; it is recovered by sorting, crushing, drying, distilling, and moulding. Because of the volcanic nature of the island it is probable that extensive reserves of sulphur are available.

Little is known of the history of sulphur mining in Japan, except that it has increased steadily and with only moderate fluctuations since the restoration.

It is probable that Japan will continue in its position as the third most important producer for some time to come.

PRODUCTION

Almost all of the sulphur produced in the world comes from the United States, Italy, Japan, Chile and Spain. The relative importance of their outputs since 1900 is shown in Table 1. Other countries produce sulphur either directly from ore or as a by-product in chemical operations. The figures for such production are not available nor is there a suitable basis for estimating its amount, but it is believed to be small, probably well under 5 per cent of the world production. The widespread occurrence of sulphur in its native state renders it easily available, and unimportant production probably takes place for local or immediate consumption in districts where no records are kept.

A constantly increasing trend in sulphur production is noted by referring to Figure 4, which shows the sulphur production of the world and of the three leading producing countries.

Table 1. - World Production of Sulphur, 1900-1929.
(In long tons)

	United States	Italy[1]	Japan[2]	Chile	Spain	Total [3]
1900	3,147	535,525	14,211	1,661	738	555,282
1901	6,867	554,203	16,287	2,037	600	597,994
1902	7,446	530,913	17,998	2,594	443	559,394
1903	35,097	545,005	22,513	3,504	1,653	607,772
1904	85,000	519,231	25,165	3,538	595	633,529
1905	220,000	559,942	24,264	3,417	600	808,223
1906	295,123	491,920	27,885	4,525	689	820,142
1907	188,878	420,229	32,803	2,859	3,555	648,324
1908	364,444	438,279	32,891	2,662	2,941	841,217
1909	273,983	428,189	36,317	4,437	3,375	746,301
1910	247,060	423,563	43,154	3,762	3,773	721,312
1911	205,066	407,620	49,481	4,380	6,476	673,023
1912	787,735	383,300	53,692	4,361	4,519	1,233,607
1913	491,080	380,209	58,509	6,542	7,381	943,721
1914	417,690	371,875	72,944	9,850	7,933	880,292
1915	520,582	352,451	71,066	9,615	9,517	963,231
1916	649,683	265,120	104,707	14,644	10,461	1,044,615
1917	1,134,412	208,501	116,224	17,787	12,681	1,489,605
1918	1,353,525	230,596	63,748	19,248	12,537	1,679,654
1919	1,190,575	222,555	49,831	18,611	11,263	1,492,835
1920	1,255,249	259,440	38,975	13,129	12,200	1,578,993
1921	1,879,150	269,547	36,013	9,517	5,170	2,199,397
1922	1,830,942	164,696	34,095	12,057	13,028	2,054,818
1923	2,036,097	252,293	36,825	11,200	8,382	2,344,797
1924	1,220,561	290,241	46,133	9,611	9,388	1,575,934
1925	1,409,262	259,428	46,962	8,929	7,859	1,732,440
1926	1,890.027	267,107	47,020	8,787	9,351	2,222,292
1927	2,111,618	300,888	60,371	12,303	10,065	2,495,245
1928	1,981,873	291,430	68,956	15,423	10,199	2,367,881
1929	2,362,389	[4] 323,000	58,718	[4] 16,000	[4] 10,000	2,770,107

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[1] Greggio sulphur.

[2] Does not include sulphur ore.

[3] Does not include scattered production throughout the world which is probably well under 5 per cent of total.

[4] Estimate.

The figures for Italy shown in Table 1 and Figure 4 are not directly comparable with the United States and other countries. The commercial sulphur of Sicily contains from 2 to 11 per cent of impurities and is known as "greggio" which is graded as "best unmixed seconds," "best unmixed thirds" and "current thirds." The refined Sicilian sulphur known as "raffinite" is presumably made from greggio sulphur. Some of the rich sulphur ore (over 40%) is ground and marketed as "Minerale di Solfo Maccianato". The amount of this material produced is small, it is largely used locally, and the sulphur content is not known. The production of this class of material is as follows:

Year	Long tons	Year	Long tons	Year	Long tons
1900....	24,147	1910....	20,961	1920....	31,983
1901....	25,412	1911....	17,133	1921....	28,405
1902....	19,684	1912....	18,125	1922....	22,347
1903....	17,125	1913....	19,779	1923....	9,316
1904....	24,507	1914....	25,309	1924....	21,948
1905....	24,726	1915....	21,783	1925....	26,821
1906....	28,322	1916....	18,297	1926....	33,088
1907....	19,160	1917....	17,988	1927....	23,487
1908....	18,611	1918....	18,792	1928....	31,051
1909....	19,204	1919....	28,729	1929....	Not available

The production of sulphur in Italy as shown in the table is for greggio sulphur only.

Japanese production figures as shown in the table do not include the production of sulphur ore. Since 1914 there has been a continuous output of this class of material. The sulphur content of the ore is not known, but it is presumably small because of the relatively low value per ton compared with the value given for sulphur. The production of sulphur ore in Japan since 1914 follows:

Year	Long tons	Year	Long tons
1914	8,696	1922	41,424
1915	16,901	1923	35,749
1916	21,148	1924	50,892
1917	13,364	1925	42,[illegible]20
1918	20,816	1926	46,545
1919	16,603	1927	16,505
1920	27,725	1928	13,109
1921	30,147	1929	Not available.

More than four times as much sulphur was produced in 1928 as at the beginning of the century. In 1912 the rapidly increasing United States production passed the decreasing Italian production and has since been the dominant factor in the world output. The recessions in United States production in 1922 and 1924 were due to curtailed operations by one of the larger producers becuase of excess sulphu stocks above ground. This is also reflected in the world's production curve.

Italian production has slowly declined, whereas the Japanese production shows a pronounced rise during the war period of 1916 and 1917.

WORLD RESERVES AND RESOURCES

Enormous quantities of sulphur exist in the earth's crust. Clarke [5] has estimated that it amounts to .06 of 1 per cent; but a large part of world reserves can not be estimated with precision. Estimates of world reserves vary from 56,000,000 to 121,000,000 metric tons. It is apparent that there is little danger of an immediate scarcity in the supply of sulphur.

The two countries with the largest reserves are Italy and the United States. Italy is estimated on a most conservative basis to have reserves of 25,500,000 metric tons, and on a more liberal basis its reserves are estimated at 84,200,000 tons. The Texas deposits probably contain in excess of 40,000,000 tons of sulphur without allowance for recent discoveries. Many other occurrences in the United States are not included in these estimates, such as those of Culberson County, Tex., where an immense tonnage is reported to exist. Some of them probably have commercial possibilities. Chile is reported to have in the provinces of Tacna and Antofagasta sulphur reserves amounting to 5,530,000 metric tons with grades ranging from 70 to 96 per cent. Spain's reserves as estimated range from 525,000 to 1,750,000 metric tons. The grades run from 15 per cent to 30 per cent. Japan probably has several million tons of 50 per cent sulphur ore.

USES, MANUFACTURES, AND SUBSTITUTES

Sulphur has a wide range of important uses and enters as a minor factor in an enormous number of industrial products. The chief producing companies in the United States are continually investigating new outlets for their product and new uses are being added. The following list of uses and industries employing sulphur, while not complete, indicates the numerous demands supplied by sulphur and its compounds:

Industries and products in which sulphur is employed

Alcohol
Alum
Aniline
Artificial fertilizers
Artificial silk
Beltings
Binders
Bleaching agent
Celluloid
Cements
Chemicals
Dyes
Ebonite
Elastics
Explosives
Fabrics
Fire extinguisher
Fireworks
Food Preservatives
Fumigant
Fungicide
Glass
Glue
Glycerin
Illuminant
Inorganic or organic acids
Insecticides
Laboratory reagent
Leather
Liquid fuel
Livestock food
Lubricants
Matches
Medicine
Metallurgy
Motor fuels
Moving-picture films
Paints
Paper
Paper bleaching
Petroleum products
Photography
Plastics
Poison
Refrigerating reagent
Rodent exterminator
Rubber hose, tires, and other rubber goods
Shoe polish
Soap
Soda
Solvent
Steel pickling and galvanizing
Storage batteries
Sugar
Tanning
Textiles
Water purification

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[5] Clarke, Frank Wigglesworth, The Data of Geochemistry: U. S. Geol. Survey Bull. 770, 1924, p. 36.

For many of these uses native sulphur competes with pyrite as a raw material for sulphur, as roasting of pyrite readily produces sulphur dioxide. In sulphuric acid manufacure the saving of freight is often a determining factor in the choice between pyrite and sulphur. About 40 per cent of the weight of pyrite becomes available for the production of sulphur dioxide, while from brimstone 98 per cent is available. Brimstone also has an advantage in requiring less grate area for burning and avoids the problem of disposal of residue such as the iron oxide residue from pyrite. In some cases pyrite can not be used because of the presence of small quantities of arsenic. For this reason brimstone acid is employed in the manufacture of medicine, food stuffs, and some chemicals. A considerable amount of sulphuric acid is made as a by-product in the smelting of metallic sulphides; the gases from the roasting operations are conducted to plants for the manufacture of sulphuric acid.

Sulphuric Acid

The most important use of sulphur in the United States is in the manufacture of sulphuric acid. The process of its manufacture includes the oxidation of sulphur (S) to sulphur dioxide (SO_2), the conversion of sulphur dioxide (SO_2) to sulphur trioxide (SO_3), and the uniting of sulphur trioxide (SO_3) with water (H^2O) to form sulphuric acid (H_2SO_4).

The oxidation of S to SO_2 is accomplished by various types of burners bot hand fed and mechanically fed. In the United States the mechanical burner is favor and is usually of the rotary type. A new type of burner in which the sulphur is melted and sprayed into the furnace has been developed. Two methods are employed in the conversion of sulphur dioxide (SO_2) to sulphur trioxide (SO_3); that is, the chamber process and the contact process.

In the chamber process the conversion from sulphur dioxide to trioxide is accomplished through the use of nitrous oxide. This with dilute sulphuric acid is permitted to trickle down through the packing of what is known as a Glover tower. Sulphur dioxide gas from the burners is led up through the packing of the tower and thus comes into intimate contact with the nitrous oxide to form the trioxide. The trioxide then passes from the tower into large lead-lined chmabers into which steam or fine sprays of water are introduced. Sulphuric acid is formed from the interaction of water and sulphur trioxide, and condenses in the chamber. The wastegases from the chamber pass up through the packing of still another tower named after Gay-Lussac, where the unused nitrous oxide meets and is absorbed by a descending stream of weak sulphuric acid. The mixture of weak sulphuric acid and nitrous oxide is then used in the Glover tower.

In the contact process the oxidation from SO_2 to SO_3 is accomplished by means of a catalyzer, a substance that increases the velocity of a chemical reaction without itself entering into the combination. Finely divided platinum is generally used for this purpose; due, however, to the high cost of platinum, other catalysts have been sought, and among them the catalytic action of vanadium and its compounds have been investigated. A new contact mass which uses no platinum is the invention of Dr. Jaeger and is described in U. S. Patents 1,675,308 and 1,675,309, dated June 26, 1928; and U. S. Patent 1,694,123, dated Dec. 4, 1928.

These complex base exchange contact masses contain vanadium as one of the catalytic elements, and it is claimed that they exceed in efficiency the best commercial platinum catalysts. This catalyst is also unaffected by poisons which hinder or retard the action of platinum catalysts. Nickel[6]claims that "within the next decade platinum catalysts for sulphuric acid will be abandoned." Plants constructed and under construction at the end of 1929, using the new vanadium contact mass, are stated to have 300,000 tons annual capacity.

In 1929 205 sulphuric acid plants of the chamber type and 62 plants of the contact type were in operation. The following table (Table 2) published by Chemical and Metallurgical Engineering [7]shows the distribution of these plants in the United States.

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[6] Nickel, L. F., New Vanadium Catalyst for Sulphuric Acid: Chem. and Met. Eng., vol. 35, No. 3, March 1928, p. 153.

[7] Chemical and Metallurgical Engineering, Sulphuric Acid Plants in the United States: vol. 37, No. 1, January, 1930, pp. 50-51.

Table 2.- Sulphuric Acid Plants in the United States [1]

Company	Location	Type		Per cent[2] U. S. Production (Estimated)	Per cent[2] U. S. Consumptio (Estimated)
		Chamber	Contact		
ALABAMA - Total		14	1	2.35	3.66
American Agricultural Chemical Co.	Montgomery	x			
du Pont de Nemours & Co.,E.I.	Mineral Springs		x		
Farmers' Fertilizer Co.	Montgomery	x			
Home Guano Co.	Dothan	x			
Jefferson Fertilizer Co.	Bessemer	x			
Planters' Chemical & Oil Co.	Talladega	x			
Roanoke Guano Co.	Roanoke	x			
Royster Guano Co. F. S.	Birmingham	x			
Standard Chemical Co.	Troy	x			
Steel Cities Chemical Co.	Ensley	x			
	Birmingham	x			
	Dothan	x			
Virginia Carolina Chemical Co.	Mobile	x			
	Opelika	x			
	Selma	x			
ARIZONA - Total		1	1	[3]	0.22
Apache Powder Co.	Douglas		x		
Calumet & Arizona Mining Co.	Douglas	x			
ARKANSAS				[3]	0.10
Southern Acid & Sulphur Co.	Augusta	x			

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[1] This table has been corrected according to information published in the March issue of Chemical and Metallurgical Engineering and information obtained from correspondence.

[2] Production and consumption percentages are recommended for comparison purposes and rough calculations only. Although these estimates are believed to be correct within 10 to 15 per cent, reliable sources for these data are not available.

[3] Production percentages for states having two or less sulphuric acid plants are lumped in the undistributed total.

Note: This tabulation of sulphuric acid plants in the United States represents, so far as is known, the first comprehensive list of the type to be published. It is realized that errors will, in all likelihood, be present in spite of the effort which has been made to check and recheck the list with all available sources for this information. Chem. & Met. will appreciate information regarding any corrections that should be incorporated in similar tabulations which may be published in the future.-Editor.

Table 2.- Sulphuric Acid Plants in the United States[1] (Contd)

Company	Location	Type		Per cent[2] U. S. Production (Estimated)	Per cent[2] U. S. Consumption (Estimated)
		Chamber	Contact		
CALIFORNIA - Total	....	6	6	4.70	4.55
American Agricultural Chemical Co.	Los Angeles	x			
Barbour Chemical Works	Melrose	x			
Dominguez Chemical Co.	Dominguez		x		
General Chemical Co.	Bay Point		x		
	El Segundo		x		
Hercules Powder Co.	Pinole (not operating)		x		
Mountain Copper Co.	Martinez	x			
Stauffer Chemical Co.	Los Angeles	x	x		
	San Francisco	x			
	Stege	x	x		
COLORADO - Total	....	1	2	0.51	0.48
du Pont de Nemours & Co., E.I.	Louviers (not operating)		x		
General Chemical Co.	Denver	x	x		
CONNECTICUT - Total	....	2		3/	3.05
Kelbfleisch Corporation	Waterbury	x			
Naugatuck Chemical Co.	Naugatuck	x			
DELAWARE				3/	0.12
General Chemical Co.	Claymont		x		
FLORIDA - Total	....	5	1	0.86	1.52
American Agricultural Chemical Co.	Pensacola	x			
American Cyanamid Co.	Tampa (Building)		x		
Armour Fertilizer Works	Jacksonville	x			
Barker Chemical Co.	Dunnellon	x			
Painter Fertilizer Co. E.O.	Jacksonville	x			
Wilson & Toomer Fertiliver Co	Jacksonville	x			

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[3] Production percentages for states having two or less sulphuric acid plants are lumped in the undistributed total.

Table 2.- Sulphuric Acid Plants in the United States [1] (Contd)

Company	Location	Type		Per cent[2] U. S. Production (Estimated)	Per cent[2] U. S. Consumption (Estimated)
		Chamber	Contact		
GEORGIA - Total		32		3.34	4.87
American Agricultural Chemical Co.	Savannah	x			
Armour Fertilizer Works	Atlanta	x			
	Columbus	x			
Blackshear Mfg. Co.	Blackshear	x			
Cotton States Fertilizer Co.	Macon	x			
Empire State Fertilizer Co.	Athens	x			
Furman Fertilizer Works	East Point	x			
Georgia Fertilizer Co.	Valdosta	x			
Home Guano Co	Columbus	x			
International Agricultural Corp.	Columbus	x			
McCabe Chemical Co.	Macon	x			
Mandeville Mills	Carrollton	x			
Morris Fertilizer Works	Atlanta	x			
Mutual Fertilizer Co.	Savannah	x			
Pelham Phosphate Co.	Pelham	x			
Phosphate Mining Co.	Savannah	x			
Reliance Fertilizer Co.	Savannah	x			
Royster Guano Co., F.S.	Macon	x			
Savannah Guano Co.	Savannah	x			
Southern Fertilizer & Chemical Co.	Savannah	x			
Southern States Phosphate Co.	Augusta	x			
Southern Sulphur Oil Co.	Athens	x			
Southern Sulphur Ore Co.	Columbus	x			
Swift Fertilizer Co.	Atlanta	x			
Tennessee Chemical Co.	Albany	x			
Trout Co.	Lagrange	x			
Virginia-Carolina Chemical Co.	Atlanta	x			
	Augusta	x			
	Columbus	x			
	Macon	x			
	Rome	x			
	Savannah	x			

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[3] Production percentages for states having two or less sulphuric acid plants are lumped in the undistributed total.

Table 2.- Sulphuric Acid Plants in the United States [1] (Contd)

Company	Location	Type		Per cent[2] U. S. Production (Estimated)	Per cent[2] U. S. Consumption (Estimated)
		Chamber	Contact		
ILLINOIS - Total	....	10	4	8.20	5.71
American Zinc, Lead and Smelting Co.	East St. Louis	x			
	Hillsboro	x			
Armour Fertilizer Works	Chicago Heights	x			
Central Chemical Co.	West Hammond	x			
Eagle-Picher Zinc Co.	Hillsboro	x	x		
General Chemical Co.	South Chicago		x		
Hegeler Zinc Co.	Danville	x			
Illinois Zinc Co.	Peru	x			
Matthiessen & Hegeler Zinc Co.	La Salle	x			
Monsanto Chemical Works	Monsanto	x	x		
	E. St. Louis	x			
New Jersey Zinc Co.	Depue		x		
INDIANA - Total	... .	1	2	1.89	4.73
Grasselli Chemical Co.	Grasselli	x	x		
Stauffer Chemical Co.	Hammond		x		
KENTUCKY					.28
Graseelli Chemical Co.	Wurtland		x		
LOUISIANA - Total	....	5	2	1.26	2.09
Armour Fertilizer Works	New Orleans	x			
Louisiana Chemical Co.	Baton Rouge		x		
Planters' Fertilizer & Chemical Co.	New Orleans	x			
Southern Acid & Sulphur Co. ..	Bossier City		x		
Swift Fertilizer Co.	New Orleans	x			
Union Seed & Fertilizer Co. ..	Gretna	x			
Virginia-Carolina Chemical Co	Shreveport	x			

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3/ Production percentages for states having two or less sulphuric acid plants are lumped in the undistributed total.

Table 2.- Sulphuric Acid Plants in the United States [1] (Contd)

Company	Location	Type		Per cent[2] U. S. Production (Estimated)	Per cent[2] U. S. Consumption (Estimated)
		Chamber	Contact		
MARYLAND - Total		10	3	8.70	6.39
American Agricultural Chemical Co.	Baltimore	x			
Baugh Chemical Co.	Baltimore	x			
Davison Chemical Co.	Baltimore	x	x		
Griffith-Boyd Co.	Baltimore	x			
Lancaster Chem. Co.	Perryville	x			
Mutual Chemical Co.	Baltimore	x			
Naval Proving Ground	Indian Head		x		
Raisin Monumental Co.	Baltimore	x			
Royster Guano Co. F. S.	Baltimore	x			
Standard Wholesale Phosphate & Acid Works	Baltimore	x	x		
Virginia-Carolina Chemical Co.	Baltimore	x			
MASSACHUSETTS - Total		6	2	3.53	2.32
American Agricultural Chemical Co.	North Weymouth	x			
Atlantic Chemical Co.	Lowell	x			
Avery Chemical Co.	Tewksbury	x			
Lowell Fertilizer Co.	Lowell	x			
Merrimac Chemical Co.	Everett	x	x		
	Woburn	x	x		
MICHIGAN - Total		2	2	0.88	2.59
American Agricultural Chemical Co.	Detroit	x			
Cleveland Cliffs Iron Co.	Marquette	x			
Detroit Chemical Works	Detroit		x		
Grasselli Chemical Co.	Ecorse		x		

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[3] Production percentages for states having two or less sulphuric acid plants are lumped in the undistributed total.

Table 2.- Sulphuric Acid Plants in the United States1/ (Contd)

Company	Location	Type		Per cent[2] U. S. Production (Estimated)	Per cent[2] U. S. Consumption (Estimated)
		Chamber	Contact		
MISSISSIPPI - Total		7		0.76	0.57
Davison-Gulfport Fertilizer Co	Gulfport	x			
International Agricultural Corp.	Tupelo	x			
Jackson Fertilizer Co.	Jackson	x			
Laurel Oil & Fertilizer Co.	Laurel	x			
Meridian Fertilizer Factory	Meridian	x			
	Hattiesburg	x			
Tupelo Agricultural Chemical Co.	Tupelo	x			
MISSOURI					
Atlas Powder Co.	Atlas		x	3/	0.98
MONTANA					
Anaconda Copper Mining Co.	Anaconda	x		3/	0.05
NEW JERSEY - Total		14	8	11.98	8.34
American Agricultural Chemical Co.	Carteret	x			
	Chrome	x			
American Cyanamid Co.	Warners	x	x		
Armour Fertilizer Works	Carteret	x			
Atlas Powder Co.	Hopatcong		x		
Calco Chemical Co.	Bound Brook	x	x		
	" "	x			
du Pont de Nemours & Co., E.I.	Deepwater		x		
General Chemical Co.	Edgewater	x	x		
Grasselli Chemical Co.	Grasselli	x	x		
	Newark	x			
	Paulsboro	x			
Hercules Powder Co.	Kenvil		x		
	Parlin		x		

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3/ Production percentages for states having two or less sulphuric acid plants are lumped in the undistributed total.

Table 2.- Sulphuric Acid Plants in the United States 1/ (Contd)

Company	Location	Type		Per cent2 U. S. Production (Estimated)	Per cent2 U. S. Consumption (Estimated)
		Chamber	Contact		
NEW JERSEY (Contd)					
Kalbfleisch Corp.	Elizabeth	x			
Mutual Chemical Co.	Jersey City	x			
Standard Oil Co. (N.J.)	Bayone (not operating)	x			
Thomas & Sons, I.P.	Paulsboro (not operating)	x			
NEW YORK - Total	....	4	2	2.27	7.29
American Agricultural Chemical Co.	Buffalo	x			
Eastman Kodak Co.	Rochester		x		
General Chemical Co.	Buffalo	x	x		
(Contact Process Co.Division)	Buffalo	x			
Robinson Brothers Co.	Brooklyn	x			
NORTH CAROLINA - Total	....	17		2.39	3.31
Acme Mfg. Co.	Wilmington	x			
American Agricultural Chemical Co.	Wilmington Columbia	x x			
Armour Fertilizer Works	Greensboro Wilmington	x x			
Caraleigh Phosphate & Fertilizer Wks.	Raleigh	x			
Dixie Guano Co.	Laurinburg	x			
McCabe Chemical Co.	Charlotte	x			
Merchants' Feed & Phosphate Co.	Charlotte	x			
Swift Fertilizer Co.	Wilmington	x			
Virginia-Carolina Chemical Co.	Charlotte Durham Navassa Selma Wadesboro Wilmington Winston Salem	x x x x x x x			

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3/Production percentages for states having two or less sulphuric acid plants are lumped in the undistributed total.

Table 2.- Sulphuric Acid Plants in the United States 1/(Contd)

Company	Location	Type		Per cent[2] U. S. Production (Estimated)	Per cent[2] U. S. Consumption (Estimated)
		Chamber	Contact		
OHIO - Total		16	3	7.20	8.43
American Agricultural Chemical Co.	Cincinnati	x			
	Cleveland	x			
American Steel & Wire Co.	Cleveland	x			
Armour Fertilizer Works	Cincinnati	x			
	Sandusky	x			
Farmers' Fertilizer Co.	Columbus	x			
Federal Chemical Co.	Columbus	x			
General Chemical Co.	Cleveland		x		
Grasselli Chemical Co.	Canton	x			
	Cleveland	x	x		
	Lockland	x			
	Niles	x			
	Toledo		x		
Jarecki Chemical Co.	Cincinnati	x			
St. Bernard Acid Works	St. Bernard	x			
Smith Agricultural Chemical Co.	Columbus	x			
Virginia-Carolina Chemical Co.	Cincinnati	x			
	Sandusky	x			
OKLAHOMA - Total			2	3/	0.07
National Zinc Co.	Bartlesville		x		
Ozark Chemical Co.	West Tulsa		x		
PENNSYLVANIA - Total		16	8	11.70	10.79
American Sheet & Tin Plate Co.	Vandergrift	x			
American Steel & Wire Co.	Donora	x			
American Zinc & Chemical Co.	Langeloth	x			
Atlas Powder Co.	Tamaqua		x		
General Chemical Co.	Newell		x		

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3/ Production percentages for states having two or less sulphuric acid plants are lumped in the undistributed total.

Table 2.- Sulphuric Acid Plants in the United States [1] (Contd)

Company	Location			Per cent[2] U. S. Production (Estimated)	Per cent[2] U. S. Consumption (Estimated)
		Chamber	Contact		
PENNSYLVANIA (Contd)					
Grasselli Chemical Co.	Beaver Falls	x			
	New Castle	x			
	Philadelphia	x	x		
Hercules Powder Co.	Emporium		x		
Kalbfleisch Corp.	Erie	x			
Lancaster Chemical Co.	Lancaster	x			
Lenning & Co., Charles	Philadelphia	x			
Merck & Co.	Philadelphia	x			
New Jersey Zinc Co.	Palmerton		x		
Pennsylvania Salt Mfg. Co.	Natrona	x	x		
	Philadelphia	x	x		
Powers, Weightman & Rosengarten	Philadelphia	x			
Trojan Powder Co.	Seiple		x		
Tunnell & Co., F.W.	Philadalphia	x			
York Chemical Co.	York	x			
United Gas Improvement Co.	Point Breeze (Phila)	x			
SOUTH CAROLINA - Total		13		2.15	2.92
American Agricultural Chemical Co.	Charlston	x			
	Columbia	x			
Anderson Fertilizer Works	Anderson	x			
Etiwan Fertilizer Co.	Charleston	x			
Maybank Fertilizer Co.	Charleston	x			
Merchants' Fertilizer & Phosphate Co.	Charleston	x			
Planters' Fertilizer & Phosphate Co.	Charleston	x			
Read Fertilizer Co.	Charleston	x			
Royster Guano Co., F.S.	Columbia	x			

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[3] Production percentages for states having two or less sulphuric acid plants are lumped in the undistributed total.

Table 2.- Sulphuric Acid Plants in the United States 1/(Contd)

Company	Location	Type		Per cent[2] U. S. Production (Estimated)	Per cent[2] U. S. Consumption (Estimated)
		Chamber	Contact		
SOUTH CAROLINA (Contd)					
Virginia-Carolina Chemical Co.	Blacksburg	x			
	Charleston	x			
	Greenville	x			
	Pon Pon	x			
TENNESSEE - Total	....	7	1	7.83	1.20
Armour Fertilizer Works	Nashville	x			
Ducktown Chemical & Iron Co.	Isabella	x	x		
Federal Chemical Co.	Nashville	x			
Read Phosphate Co.	Nashville	x			
Tennessee Copper & Chemical Co.	Copper Hill	x			
Victor Chemical Works	Nashville	x			
Virginia-Carolina Chemical Co.	Memphis	x			
TEXAS - Total	....	2	4	3.91	4.56
Armour Fertilizer Works	Houston	x			
Gulf Refining Co.	Port Arthur		x		
Southern Acid & Sulphur Co. ..	Port Arthur		x		
Texas Chemical Co.	Fort Worth		x		
	Houston		x		
United Chemical Co.	Dallas	x			
UTAH	....			3/	0.10
Hercules Powder Co.	Bacchus		x		
VIRGINIA - Total	....	8	1	2.90	3.51
American Agricultural Chemical Co.	Alexandria	x			
General Chemical Co.	Pulaski		x		

1/ This table has been corrected according to information published in the March issue of Chemical and Metallurgical Engineering and information obtained from correspondence.

2/ Production and consumption percentages are recommended for comparison purposes and rough calculations only. Although these estimates are believed to be correct within 10 to 15 per cent, reliable sources for these data are not available.

3/ Production percentages for states having two or less sulphuric acid plants are lumped in the undistributed total.

Table 2.- Sulphuric Acid Plants in the United States[1] (Contd)

Company	Location	Type		Per cent[2] U. S. Production (Estimated)	Per cent[2] U. S. Consumption (Estimated)
		Chamber	Contact		
VIRGINIA - (Contd)					
Richmond Guano Co.	Richmond	x			
Robertson Chemical Corp.	Norfolk	x			
Royster Guano Co., F.S.	Norfolk	x			
Virginia-Carolina Chemical Co.	Lynchburg	x			
	Pinners Point	x			
	Portsmouth	x			
	Richmond	x			
WASHINGTON				3/	0.19
du Pont de Nemours & Co., E.I.	du Pont	x	x		
WEST VIRGINIA - Total		2		3/	1.31
Fairmont Chemical Co.	Fairmont	x			
United Zinc Smelting Corp.	Moundsville	x			
WISCONSIN - Total		1	2	0.25	0.75
du Pont de Nemours & Co., E.I.	Barksdale	x	x		
National Zinc Ore Separating Co.	Cuba City		x		
Undistributed				10.44	2.95
Total		205	62	100.00	100.00

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[1] This table has been corrected according to information published in the March issue of Chemical and Metallurgical Engineering and information obtained from correspondence.

[2] Production and consumption percentages are recommended for comparison purposes and rough calculations only. Although these estimates are believed to be correct within 10 to 15 per cent, reliable sources for these data are not available.

[3] Production percentages for states having two or less sulphuric acid plants are lumped in the undistributed total.

The contact plants in 1929 produced approximately 3,000,000 tons of sulphuric acid reduced to a 50° B. basis. This represents about 35 per cent of the total production. The chamber process is generally used in the manufacture of acids of lower concentrations and is the source of supply of weak sulphuric acid for the fertilizer industry, whereas acids of higher concentrations (over 60° B.) and oleum (fuming sulphuric acid) are generally made by the contact process.

Sulphuric acid used in industries other than the fertilizer industry consumes a considerable part of production. It is an essential and important commodity in the industrial arts, such as pickling for the preparation of material for galvanizing, tinning, and enamelling. It also enters largely into the refining of various petroleum products. The liquid solution of ordinary storage batteries is sulphuric acid. As an electrolyte it is used in the refining of copper and is very important in the manufacture of chemicals and drugs.

The estimated distribution of the consumption of sulphuric acid reduced to a 50° B. basis is shown in Table 3 [8] for 1927, 1928, and 1929.

Table 3.- Estimated distribution of 50° B. sulphuric acid

Consuming industries	1929 Tons	1928 Tons	1927 Tons
Fertilizers	2,360,000	2,300,000	1,925,000
Petroleum refining	1,570,000	1,350,000	1,325,000
Chemicals	820,000	745,000	725,000
Coal products	820,000	740,000	732,000
Iron and steel	770,000	670,000	685,000
Other metallurgical	625,000	570,000	700,000
Paints and pigments	215,000	205,000	210,000
Explosives	195,000	170,000	183,000
Textiles	85,000	78,000	135,000
Rayon	145,000	105,000	(not shown)
Miscellaneous	320,000	292,000	290,000
Total	7,925,000	7,225,000	6,935,000

The total estimated production of sulphuric acid in 1929 was estimated by Chemical and Metallurgical Engineering to be 7,926,000 tons on a 50° B. basis. Native sulphur, however, was not the raw material for all of this production. Estimates from the same source show that in 1929, 1,135,000 tons of native sulphur were used in the manufacture of sulphuric acid. This is equivalent to 5,606,000 tons of 50° B. acid or 70.8 per cent of total acid produced. The sulphuric acid produced from pyrite amounts to 20.6 per cent of the total; that from other sources, chiefly a by-product of copper and zinc smelting, is 8.6 per cent.

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[8] Chemical and Metallurgical Engineering, vol. 37, No. 1, Jan. 1930, pp. 50-51.

In the United States most sulphuric acid is produced by burning sulphur; of the remainder the larger part is furnished by roasting of pyrites or by sulphur dioxide recovery from smelter fumes. In England, until recently, sulphur had been almost entirely replaced by pyrites for the manufacture of sulphuric acid, but at present an increasing quantity of acid is being made from sulphur. By-product sulphur. By-product sulphur dioxide from the zinc industry is also contributing toward the decline in pyrites consumption. Elsewhere on the continent pyrite forms an important source of sulphur for the manufacture of sulphuric acid. European manufacturers continue to display interest in natural sulphates (particularly gypsum) as substitutes for sulphur and pyrites in the manufacture of sulphuric acid. In Germany the Bayer factory at Leverkusen is said to have a yearly capacity of from 40,000 to 50,000 metric tons of sulphuric acid, and further extensions are contemplated. Molitor[9] has described various methods of utilizing calcium sulphate as a source of sulphuric acid. The Bayer process involves the heating of gypsum, clay, and coal with some additions of sand and slag. The sulphur dioxide gases evolved are purified and oxidized to sulphuric acid. While this method accounts for less than 4 per cent of the German output of sulphuric acid, it exceeds the amount of sulphuric acid made from elemental sulphur, and German economists are urging its use because of the abundant local supplies of gypsum. Raw materials for German sulphuric acid production in order of their present quantitative production are pyrites, zinc blende, sulphur by-product from gases, gypsum, and elemental sulphur. France is also constructing plants for the manufacture of sulphuric acid from sulphates.

Pulp and Paper

Another important use of sulphur is in the manufacture of wood pulp, and paper. While there are several processes for the manufacture of pulp, sulphur is used chiefly in the sulphite process. Wood contains a large proportion of cellulose, the substance of which paper is made, which is cemented together by resinous and gummy materials that must be decomposed. This is done by sulphite or bisulphite of calcium or magnesium formed by the passage of the gas of burning sulphur through lime water. The amount of sulphur used per ton of pulp varies between 220 and 300 pounds [10] Thorpe [11] states that about 280 pounds of sulphur are required for every ton of wood pulp produced.

In the sulphate method, sulphur is employed indirectly through the use of salt cake or sodium sulphate, which is largely a by-product of other industries. The largest amount of chemical fiber produced is made by the sulphite process.

Pyrite is used to a limited extent in the sulphite method of producing wood pulp. The bisulphite manufactured is added to the wood chips in a very dilute, solution; 5 per cent of the total SO_2 may be regarded as the maximum, and of this 2 per cent is purposely uncombined. It is essential that not more than traces of sulphuric acid be present, otherwise the pulp is affected injuriously. These two facts account for sulphur's not having been replaced by pyrites in the manufacture of wood pulp bisulphites, because the dilute solution employed makes it practically necessary to manufacture the bisulphite where the wood pulp is made. The cost of transport per unit of sulphur available for conversion into sulphur dioxide is therefore a serious consideration. Moreover, it has not been found practicable to limit sufficiently the quantity of sulphuric acid present if the sulphurous acid is made from pyrites, due to the catalytic action of the ore itself. In using pyrite instead of sulphur as a raw material for the generation of SO_2, the quality of the gas is more variable and requires special purification. The gas also carries with it considerable quantities of mechanical impurities which have to be removed by dirt catchers or dust chambers, by filtering, or by electrical precipitation. The amount of SO_3 is usually much higher and it has to be removed in a special washing process; this is due to the fact that sulphur dioxide is more easily oxidized to sulphur trioxide in the presence of certain substances, as iron oxide. In the burning of sulphur, the only so-called catalyzer present is the metal of the burners and piping; while in the pyrite process, the ore itself acts as a contact substance and accelerates the formation of SO_3 even at the lower temperatures.

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[9] Molitor, Heinrich, Die Nutzbarmachung der Gipsschofelsaure: Chem.Ztg., vol. 51, No. 35, May 4, 1927, pp. 324-332, 370-373.

[10] Johnsen, Bjarne, The Manufacture of Pulp and Paper, New York, 1927, Vol. 3, p. 84.

[11] Thorpe, Edward, Dictionary of Applied Chemistry: London, 1919, vol. 5, p. 294.

Fertilizer

An important use of sulphur (as sulphuric acid) is in the manufacture of fertilizers, mostly acid phosphate, which forms a large part of the mixed fertilizers used in this country. Of the total production of 7,335,795 tons of 50° B. acid by all industries in the United States in 1927, 27.9 per cent was reported by establishments in the fertilizer industry. The acid phosphate is prepared by treating ground phosphate rock, known as floats, with sulphuric acid for the purpose of making the phosphates soluble and so rendering them available for plant food. Aside from its application to phosphate fertilizers, sulphur itself is often used as a fertilizer. Small additions to the soil have been found to increase materially the weight of many vegetables, sometimes as much as 40 per cent. As sulphur is not effective when applied to sterilized soil it has been suggested that its effect is that of modifying soil bacteria. It is asserted that sulphur influences the chlorophyll so that plants grown upon soil containing sulphur are much more green than otherwise. Its application to soils also serves to increase the acidity which is particularly desirable under certain conditions. Sulphuric acid is used to a large extent in the manufacture of ammonium sulphate which is also an extremely valuable fertilizer.

Fungicide and Insecticide

Sulphur is used extensively, especially in Europe, to prevent the growth upon grapes and shoots of vines of the microscopic mold fungus Oidium which if allowed to develop, causes the vine leaves to dry up; as a result the grapes when ripe produce an unsound wine. The sulphur employed for this purpose is largely in the form of flowers of sulphur, although winowed sulphur is used. Aside from the above, sulphur is viticulture in the form of Bordeaux mixture, which consists of a mixture of sulphur, copper sulphate, and various porous substances. This is applied to grapes and shoots of the vines. Flowers of sulphur is also used effectively to prevent the growth of mold on hops, which is similar in character to that occurring on grape vines. The fungus growing on the surface of the leaves will form a white powdery spot on the buds of hop cones and prevent or impair their development, rendering the hops practically useless.

The efficiency of sulphur as a preventative of the growth of the Oidium is considered to be largely dependent upon its physical condition. Thus, flowers of sulphur contain a certain portion of amorphous sulphur which is more easily oxidized than crystalline sulphur, even when in a very fine state of subdivision. It is believed that by air exposure, minute quantities of sulphurous acid and sulphuric acid are formed which cause the destruction of the fungus.

As an insecticide, sulphur is dusted on trees and plants or combined with lime as a lime-sulphur spray. Powdered sulphur is used to combat the cotton flea. Sulphur is applied to soils to check potato scab, and is used in various animal dips for the destruction of parasites. In recent years its use as an insecticide has become more and more important. It was reported [12] that sulphur dusting had been used successfully in preventing rust in the grain fields of Canada.

Petroleum Industry

Many thousand tons of sulphuric acid are used in connection with the refining of oils, advantage being taken of the variations in the susceptibility to attack by sulphuric acid of some of the constituents of crude oil, particularly unsaturated hydrocarbons and substances that impart a dark color as well as an unpleasant odor.

For some uses oil containing sulphur is desirable, as for metal-cutting oils used largely by the metal-working industries for thread cutting, turret lathes, and other machine work. For this purpose sulphur is first incorporated with an animal or vegetable oil base and subsequently added in proper proportion to a petroleum oil.

Sulphur Dioxide

Sulphur dioxide is marketed usually in the liquid form and is moved in tank cars or drums. It has found wide use in the chemical field and is now the major refrigerant in small refrigerating systems. It is employed for bleaching paper, straw, wood, wool, silk, etc., and is used by cotton bleachers as an antichlor. It is also used as a mordant in the dye industry. Sulphur dioxide extensively used for the preservation of fruit, wine, meat, sugar, and syrups. The fact that sulphur dioxide has very little "inverting" action on sugar makes it a suitable preservative of such foods. It is used in the treatment of grapes loaded into cars, as it prevents mold formation. Sugar refiners employ sulphur dioxide in the treatment of sugar juices. In oil refineries it is used to dissolve out certain objectionable impurities. For the rapid disinfection of ships and for destroying rats and other vermin the portable containers of sulphur dioxide are very convenient.

The sulphur dioxide in this country is largely made from the burning of sulphur. The production in the United States is given as follows:

Production of Sulphur dioxide in the United States, 1927 - 1923, inclusive

	1927	1925	1923
Number of establishments	4	4	4
Pounds	10,133,983	8,861,341	6,575,995
Value	$687,855	$635,738	$414,049

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[12] World Trade Notes, vol. 2, No. 50, December 10, 1928, p. 2.

Rubber Industry

Ordinary rubber before vulcanizing is weak, softened by moderate heat, rendered stiff by cold, soluble in gasoline or benzol, and is quite useless for most industrial needs. The rubber industry is built around the discovery of vulcanization which renders the rubber more suitable for use. Vulcanization of rubber is effected by the addition of ground sulphur to the rubber. Other materials have been used as vulcanizing agents but sulphur is commonly used. Sulphur chloride, a solvent for sulphur, is used for vulcanizing caoutchouc.

The differences in the various grades of vulcanized rubber are due mainly to the proportion of sulphur mixed with the rubber material in vulcanizing the mixtures. Soft rubber goods carry from 2½ per cent to 10 per cent of sulphur; most rubber compounds carry from 3 per cent to 5 per cent; and hard rubber compositions carry from 10 per cent to 15 per cent of sulphur.

Explosives

Sulphur in one form or another has been used in the manufacture of explosives since Orientals first learned the secret of mixing saltpetre, sulphur, and charcoal in the thirteenth century. The use of sulphur as such in explosives is now practically confined to black powder, which contains about 10 per cent by weight of sulphur. Some sulphur is also used in granulated dynamite. Smaller amounts are employed in the manufacture of fireworks, especially in China. Sulphuric acid is employed extensively in the manufacture of high explosives.

Miscellaneous

Sulphur is occasionally introduced into glass; the colors produced by it are due to molecular dispersed sulphur present in the form of polysulphides. Sulphur is an impurity and objectionable in the manufacture of steels; however, it is added to some steels for special purposes, notably for the making of screw stock.

Sulphur cements, which consist of sulphur and inert minerals when applied hot, are useful in anchoring metal into stone.

Although sulphur is one of the cheapest of raw materials, its use has been almost wholly confined until recently to that of a chemical reagent, as in the uses outlined above. It is chemically inert. In its usual elemental form it lacks strength and is easily crushed; but when it is properly supported in a porous vehicle such as paper board or Portland cement, it not only adds greatly to the strength of the carrier, but enables the combined structure to resist the action of many destructive chemicals. Concrete containing 15 per cent of cement has shown, when impregnated with sulphur, ten times the tensile strength of plain specimens.[13] Large electrolytic cells made of concrete impregnated with molten sulphur have been in use for two years. This same principle may be applied to certain materials such as sandstone and limestone, increasing their strength and reducing their porosity. Sulphur may be mixed in a molten state with sand, slag, graphite, and other granular materials to produce substances which are strong, hard, and proof against both acid and base. Textiles and fabrics may likewise be impregnated with sulphur.

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[13] Engineering and Mining Jour. Sulphur in Construction: vol. 125, No. 12, March 24, 1928, p. 489.

Wood may be impregnated with sulphur by methods similar to those in use in lumber preservation; and as sulphur melts to a mobile liquid at a temperature a little above the boiling point of water, there is little difficulty in securing effective penetration. Wood thus treated should prove useful in the construction of pickling tubs for metal industries and tanks for chemical works.

CONSUMPTION OF SULPHUR

At the beginning of the present century the consumption of sulphur in the United States was impeded in proportion to an increasing consumption of pyrite, with the Anglo-Sicilian Sulphur Co. dominating the sulphur market. The amount of sulphur consumed in 1900 was 44.5 per cent more than that of 1891 while the use of iron pyrite as a source of sulphur had increased 151.4 per cent over the same period. With the advance in price of Sicilian sulphur, acid makers in the United States commenced using pyrite, until in 1902 pyrite was the source of 65 per cent of the sulphur consumed. Even sulphite pulp mills were turning to pyrite as a source of sulphur. However, with the successful application of the Frasch process to the American sulphur deposits the situation began to take on a different aspect soon after 1903. Consumption was largely confined to the wood-pulp industry until about 1917, and sulphur had not yet been extensively adopted for acid making. It was estimated that two-thirds of our sulphur output was consumed in paper mills. At this time, however its use in place of pyrite for acid making commended on a large scale, principally on account of the world war. The need for transportation facilities for essential traffic between the United States and Europe resulted in drastic curtailment of bottoms engaged in other traffic. In 1919 the Spanish pyrite supply failed, and a third American sulphur producer entered the market. This caused sulphuric acid manufacturers to turn to sulphur for their product, and at the close of the war many of the industries continued to use sulphur rather than change their plants back to handle pyrites.

In 1921 the normal consumption of sulphur in the United States and Canada was about 750,000 tons a year, of which between 15 per cent and 20 per cent of the total was used by acid phosphate manufacturers. World consumption in 1922 was estimated at 1,500,000 tons, with the United States and Canada absorbing 1,000,000 tons; in 1923 it was estimated at approximately the same figure, with Australia consuming 50,000 tons, France, 100,000 tons, Germany, 30,000 tons, and Great Britain 85,000 tons.

The consumption in 1925 was said to be 25 per cent higher than the average for the last five years; 2,250,000 tons was consumed by the world, and 1,200,000 tons was used by the United States.

The consumption of sulphur in the United States for 1927, 1928 and 1929 by various industries has been estimated in Chemical and Metallurgical Engineering as follows:

Sulphur consumed in the United States, 1927-1929, inclusive

Use	1929, tons	1928, tons	1927, tons
Heavy chemicals	560,000	520,000	490,000
Fertilizer and inseticides .	415,000	345,000	300,000
Pulp and Paper	265,000	250,000	260,000
Explosives	67,000	60,000	65,000
Dyes and coal tar products .	47,000	42,000	40,000
Rubber	43,000	40,000	35,000
Electrochemicals	23,000	21,000	20,000
Fine chemicals	15,000	14,000	13,000
Paint and varnish	5,000	5,000	5,000
Food products	5,000	5,000	3,000
Petroleum products	-	1,000	1,000
Miscellaneous	136,700	123,000	118,000
Total	1,581,700	1,426,000	1,342,000

MARKETING AND PRICE OF SULPHUR

Sulphur comes into commerce in several forms such as crude, flour, refined, flowers of sulphur, and precipitated or milk of sulphur.

The crude sulphur produced in the United States is the regular run-of-mine sulphur and is guaranteed to contain 99.5 per cent of pure sulphur and often contains as high as 99.9 per cent. The primary marketing points for crude sulphur are the mines from which shipments are made direct to consumers in any quantity. Secondary marketing points are the Gulf ports of Galveston, Texas City, and Freeport, from which shipments are made to foreign countries; and the Atlantic coast ports where shipments are again made by rail. The chief distributing points on the Atlantic coast are New York, Baltimore, Portland and Searsport, Me., and Quebec, Canada; on the Pacific Coast are Portland, Oreg., and Vancouver, B. C., and in Europe are Marseille, Manchester, Hamburg, and Rotterdam.

Commercial flour sulphur is the crude sulphur that has been ground and sized. It is often subsequently graded and marketed according to certain specifications. It is usually shipped in burlap sacks containing about 100 pounds net. This product is used extensively as a fungicide or insecticide and in the manufacture of rubber.

Refined sulphur is made by distilling and condensing crude sulphur. Often the sulphur is caught in a small hot receptacle in the molten state, cast into sticks and sold as roll sulphur. Roll sulphur is shipped in barrels or bags and is used largely as a fumigant. Refined sulphur is also ground and marketed in 100 pound bags for certain uses.

Flowers of sulphur is sublimed sulphur which is caught in dust form. Flowers of sulphur are usually marketed in 100 pound bags and is used largely for medicinal purposes; it is preferred in some European countries for dusting grape vines.

Milk of sulphur or precipitated sulphur is the white or gray amorphous sulphur deposited by the decomposition of an aqueous solution of calcium polysulphide (obtained from flowers of sulphur and lime). Milk of sulphur is used largely for medicinal purposes.

The prices of the various grades of sulphur as given by the Oil, Paint, and Drug Reporter in January, 1930, are as follows:

Sulphur, crude, mines, car lots, bulk	long ton	18.00	21.00
spot, nearby, car lots	long ton	21.00	-
ex vessel, New York, Philadelphia, Baltimore, Southern ports, bulk	long ton	22.00	25.00
Boston, Portland, bulk	long ton	22.50	25.50
flour, commercial, bags	100 lbs.	1.55	2.10
barrels	100 lbs.	1.90	2.45
extra fine, bags	100 lbs.	2.40	3.00
superfines, bags	100 lbs.	2.40	2.80
barrels	100 lbs.	2.55	3.10
Rubbermakers, bags	100 lbs.	2.20	2.80
barrels	100 lbs.	2.55	3.10
refined, extra fine, bags	100 lbs.	2.80	3.35
barrels	100 lbs.	3.15	3.17
heavy bags	100 lbs.	2.50	3.05
barrels	100 lbs.	2.85	3.40
light, bags	100 lbs.	2.60	3.15
barrels	100 lbs.	2.95	3.50
rubbermakers, bags	100 lbs.	2.60	3.15
Flowers, bags	100 lbs.	3.10	3.65
barrels	100 lbs.	3.45	4.00
precipitated, kegs	lbs.	.15	.17
roll, bags	100 lbs.	2.25	2.70
barrels	100 lbs.	2.40	2.85

The general demand for sulphur is the greatest influence on price, but due to competition the price of pyrite is an important factor in determining the price of sulphur.

The price of crude sulphur from 1909 to 1915 was about $18. a ton f.o.b. cars at the mine and $22 ex vessel at New York. During the war the prices of sulphur rose materially. Early in the fall of 1917 the fertilizer committee of the Chemical Alliance acting with the consent of the Council of National Defense made informal arrangements for a price on crude sulphur of $22 per long ton f.o.b. mines. This policy continued until June 7, 1918, when the War Industries Board took more direct control of supplies of the sulphur. On June 27, 1918, the War Industries Board by resolution, approved by the President on July 2, 1918, assumed control of the production and distribution of all sulphur materials. This control and price of $22 per long ton was in effect until January 1, 1919. Since this time active competition between sulphur producers has caused a decline in the price of sulphur to $14 to $15 a ton in 1922. Subsequently, prices have improved, and on January 1, 1930, the prices quoted in the trade journals were $18 to $21 f.o.b. mines, Texas.

The following table shows the wholesale prices of sulphur per long ton f.o.b. mines. Prices shown are mostly on contract, and the two prices represent the range between the costs to buyers of large quantities, who receive the benefit of minimum price, and to buyers of smaller amounts, who pay a price which approximates the maximum.

Table 4.- Sulphur or Brimstone (Wholesale) Per Long Ton in Cars, F. O. B. Mines

(Oil, Paint and Drug Reporter)

Year	January 1	April 1	July 1	October 1
1920	28.00 - 32.00	28.00 - 32.00	20.00 - —	20.00 - 22.00
1921	20.00 - —	16.00 - 20.00	15.00 - 16.00	15.00 - 20.00
1922	15.00 - 20.00	14.00 - 20.00	14.00 - 20.00	14.00 - 20.00
1923	14.00 - 15.00	14.00 - 15.00	14.00 - 15.00	14.00 - 15.00
1924	14.00 - 15.00	14.00 - 15.00	14.00 - 15.00	14.00 - 15.00
1925	14.00 - 15.00	14.00 - 15.00	15.00 - 16.00	15.00 - 16.00
1926	17.00 - —	19.00 - —	19.00 - —	18.00 - 19.00
1927	18.00 - 19.00	18.00 - 19.00	18.00 - 19.00	18.00 - 19.00
1928	18.00 - 19.00	18.00 - 19.00	18.00 - 19.00	18.00 - 19.00
1929	18.00 - 20.00	18.00 - 21.00	18.00 - 21.00	18.00 - 21.00

STATISTICS OF IMPORTS AND EXPORTS

The three countries exporting sulphur are the United States, Italy, and Japan. The trend of exports from these countries is shown graphically in Figure 5.

UNITED STATES

In the last quarter century, the United States has risen from a position of large imports and no exports to a position of no imports and large exports, which are more than three times the exports of Italy, the only other exporter of any consequence. In 1922, the Sulphur Export Corporation was organized under the Webb-Pomerene Act by the principal sulphur producers in the United States, for the more efficient handling of the foreign sulphur trade of the United States. It is understood that this organization is still in effect. The trend of United States exports is shown in Table 5 and the distribution of exports from 1924 to 1928 is shown in Table 6. The figures for the United States are for American crude which contains more than 99.5 pure sulphur. The chief export markets at present for American sulphur are Canada, Germany, France, Australia, and the United Kingdom. Much of the sulphur exported to Germany is transhipped to other smaller European nations. Cargoes of sulphur consigned to German ports may be sold en route and redirected by radio, or they may arrive in Germany and be transferred in small lots to a number of smaller vessels capable of movement into ports inaccessible to the original vessel. The exports of sulphur from Germany in 1928 were equivalent to 63 per cent of the imports. Countries importing sulphur from Germany in 1928 were Sweden (21,036 metric tons), Finland (22,165 tons), Great Britain (2,594 tons), Russia (2,820 tons), British India (1,874 tons), Portugal (967 tons), and Danzig (934 tons).

ITALY

The Italian exports of sulphur since 1900 have shown a constant tendency toward decrease.

The trend of sulphur exports from Italy is shown in Table 7. The figures are for Italian crude "greggio" sulphur and various grades of refined. Much of Italy's sulphur is exported to the neighboring states, mostly those bordering on the Mediterranean; however, the largest single nation importing sulphur from Italy is the United Kingdom. Table 8 shows the distribution of Italian exports of sulphur from 1924 to 1928.

JAPAN

Japanese exports of sulphur increased slowly and steadily from the beginning of the century until 1917, when a peak of 85,000 long tons was reached. Subsequently exports declined rapidly and have been of minor importance in the last decade. Table 9 shows the trend of Japanese exports. The foreign trade of sulphur from Japan is chiefly with the neighboring Asiatic countries and is not extensive due to lack of industrial development in these countries. The distribution of Japanese exports of sulphur is shown in Table 10.

Table 5.- Crude sulphur imported into and exported from the United States, 1900-1928

Year	Imports for consumption		Exports	
	Long tons	Value	Long tons	Value
1900	167,712	$2,942,994	-	-
1901	175,209	3,287,906	-	-
1902	171,380	3,357,650	-	-
1903	191,003	3,709,690	-	-
1904	127,996	2,462,360	1/3,000	1/
1905	82,961	1,528,136	11,522	2/
1906	72,404	1,282,873	14,437	$289,474
1907	20,399	355,944	35,925	734,749
1908	19,620	318,577	27,894	561,534
1909	28,800	492,962	37,142	736,928
1910	28,656	496,073	30,742	552,941
1911	24,200	434,796	28,103	545,420
1912	26,885	494,778	57,736	1,076,414
1913	15,122	286,209	89,221	1,599,761
1914	23,610	398,984	98,163	1,807,324
1915	24,647	405,990	37,312	724,679
1916	21,289	358,416	128,755	2,505,857
1917	973	20,176	152,736	3,500,819
1918	55	1,692	131,092	3,626,638
1919	77	1,997	224,712	6,325,552
1920	44	1,722	477,450	8,994,350
1921	4	226	285,762	4,524,768
1922	1/ 167	6,453	485,664	7,095,628
1923	2/ 465	21,535	472,525	7,105,260
1924	2/ 1,005	40,293	482,114	7,792,854
1925	2/ 100	4,411	629,401	11,000,235
1926	2/ 48	1,052	576,966	10,918,394
1927	2/ 3,384	34,487	789,274	16,254,227
1928	2/ 4,787	21,320	685,051	14,345,075

1/ Composed of 130 tons of crude sulphur, imported Jan. 1 to Sept. 21, and 37 tons of sulphur and sulphur ore, imported Sept. 22 to Dec. 31.

2/ Classified as "sulphur and sulphur ore."

TABLE 6--SULPHUR EXPORTED FROM THE UNITED STATES, 1934 to 1938, BY DESTINATION

Destination	1934				1935				1936				1937				1938			
	Sulphur or brimstone		Refined, sublimed, and flowers of		Sulphur or brimstone		Refined, sublimed and flowers of		Sulphur or brimstone		Refined, sublimed, and flowers of		Sulphur or brimstone		Refined, sublimed, and flowers of		Sulphur or brimstone		Refined, sublimed and flowers of	
	Long tons	Value	Pounds	Value	Long tons	Value	Pounds	Value	Long tons	Value	Pounds	Value	Long tons	Value	Pounds	Value	Long tons	Value	Pounds	Value
North America:																				
Canada	119,281	$2,921,586	1,769,984	$34,807	126,631	$2,019,205	2,796,209	$70,058	159,416	$2,960,844	3,574,691	$78,484	168,141	$2,987,697	8,038,529	$139,990	159,664	$2,897,730	7,562,023	140,604
Central America	81	3,865	192,739	5,617	21	978	257,947	7,116	134	4,241	223,699	6,606	94	2,683	413,399	9,861	126	3,690	352,299	8,887
Mexico	9,140	116,998	1,424,529	30,436	13,944	227,899	1,293,410	25,108	18,842	318,219	1,276,029	25,564	12,463	269,604	1,775,491	37,539	14,829	317,192	1,475,211	31,305
Newfoundland and Labrador	—	—	2,435	138	3,334	50,294	1,174	105	6,137	115,326	1,605	58	4,152	76,686	25,208	562	7,751	148,448	44,685	971
West Indies and Bermuda	2,556	38,875	112,026	3,575	2,541	36,991	89,948	3,222	2,566	38,144	149,024	4,494	4,001	56,089	210,763	5,945	3,022	42,907	171,124	7,439
	128,978	2,079,323	3,506,713	74,571	145,471	2,335,348	[illegible]	105,609	187,085	3,433,774	5,225,238	115,206	185,851	3,392,759	[illegible]	194,017	185,392	3,409,967	9,609,342	189,206
South America:																				
Argentina	7,380	117,011	—	—	8,200	131,500	39,600	2,340	13,555	249,200	125,150	2,378	6,480	138,180	—	—	8,680	182,280	1,800	39
Brazil	2,131	33,039	144	11	3,222	48,966	34,874	739	2,109	52,981	790,434	13,323	3,045	67,215	2,762,374	55,875	5,359	122,759	2,374,781	45,424
Colombia	30	1,444	117,075	4,040	4,067	65,757	63,253	2,330	5	282	60,653	3,444	—	—	143,690	4,558	—	—	120,754	3,906
Uruguay	—	—	—	—	150	3,600	334,000	4,400	—	—	1,008,360	15,087	—	—	1,249,159	22,025	—	—	2,239,980	31,164
Other	984	24,681	232,994	4,713	962	30,492	194,062	4,332	8	255	72,040	1,699	2,310	49,074	165,547	3,067	161	4,131	289,492	5,311
	10,445	176,175	350,213	8,764	16,601	280,315	665,009	14,041	15,677	302,718	2,046,637	35,931	11,835	254,439	4,320,770	85,525	14,200	309,170	5,026,207	85,844
Europe:																				
Belgium	3,502	58,413	—	—	11,608	280,975	—	—	—	—	43,950	495	9,119	205,343	1,014,310	17,337	10,970	243,791	2,662,213	39,067
Finland	6,300	95,300	—	—	—	—	—	—	—	—	39,520	594	2,680	52,217	—	—	1	37	—	—
France	92,918	1,527,833	4,108	112	110,684	1,996,157	—	—	91,735	1,828,430	1,122,000	17,881	126,664	2,790,698	414,850	5,961	109,348	[illegible]	130,900	2,006
Germany	79,906	1,358,474	—	—	136,972	2,638,285	—	—	109,479	2,160,077	—	—	175,511	3,790,977	8,355,410	117,835	125,659	[illegible]	18,025,199	245,157
Netherlands	21,305	358,059	1,510	144	40,909	781,217	—	—	20,158	411,773	—	—	50,775	1,104,779	—	—	[illegible]	1,102,995	922,112	14,139
Norway	1,304	19,560	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Portugal	—	—	—	—	—	—	—	—	17,600	303,600	—	—	5,200	109,200	—	—	—	—	—	—
Spain	9,889	155,35	—	—	6,346	145,592	—	—	6,227	126,596	675,827	11,921	12,069	262,509	540	31	11,798	243,677	—	—
United Kingdom	38,456	591,424	14,348	1,331	30,398	557,522	226,913	4,177	27,340	518,972	898,357	[illegible]	36,450	745,875	2,793,435	48,155	44,098	924,165	1,959,846	28,522
Other	7,627	110,432	—	—	2,114	36,452	640	96	—	—	—	—	3,696	[illegible]	323,300	5,216	4,750	[illegible]	2,351,675	[illegible]
	259,009	4,274,348	19,966	1,587	341,030	6,376,000	227,553	4,273	271,539	5,347,448	2,779,354	44,220	422,104	9,134,852	12,901,945	[illegible]	354,852	7,867,512	[illegible]	[illegible]
Asia	40	[illegible]	130,921	2,782	2,752	[illegible]	151,442	2,801	2,751	55,045	546,518	[illegible]	112	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Africa:																				
Algeria and Tunisia	7,550	121,700	—	—	7,700	138,700	—	—	6,804	138,781	—	—	8,496	180,864	—	—	4,428	98,213	—	—
British East	—	—	—	—	7,700	138,600	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mozambique	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1,900	41,400	25,000	371
Portuguese East	—	—	—	—	1,500	25,500	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Union of South Africa	5,000	85,000	604	50	15,100	[illegible]	50,344	1,096	5	153	51,508	838	20,307	419,337	217,043	3,853	11,078	243,716	392,029	6,382
	12,550	206,700	604	50	32,000	540,300	50,344	1,096	6,809	133,934	51,508	838	28,803	599,201	217,043	3,853	17,306	[illegible]	417,029	6,753
Oceania:																				
Australia	58,827	982,593	443,842	11,225	71,530	1,124,258	621,533	19,585	66,507	1,178,132	1,097,090	34,626	114,593	2,337,020	2,533,157	46,076	85,500	1,799,341	2,422,835	43,789
New Zealand	12,265	171,710	94,750	2,338	20,017	299,909	227,310	5,522	26,618	464,343	255,770	5,932	25,976	533,236	365,590	10,201	22,801	475,456	409,310	9,714
Other	—	—	—	—	—	—	112	19	—	—	—	—	—	—	—	—	—	—	—	—
	71,092	1,154,303	538,592	13,563	91,547	1,424,167	848,955	25,126	93,125	1,642,475	1,352,860	30,558	140,569	2,870,256	2,898,747	56,277	108,301	2,275,797	2,832,145	53,503
	482,114	7,792,354	4,546,009	131,347	629,401	11,000,235	8,391,791	153,546	576,965	10,918,394	12,002,105	236,146	789,274	16,254,227	31,419,221	544,373	685,051	14,345,075	44,538,508	704,768

Table 7.- Exports of sulphur from Italy (long tons)

Year	Quantity	Year	Quantity
1900	471,571	1915	289,266
1901	309,059	1916	321,279
1902	432,305	1917	116,470
1903	454,004	1918	189,191
1904	430,164	1919	118,556
1905	375,110	1920	145,915
1906	331,027	1921	167,119
1907	292,681	1922	110,625
1908	324,880	1923	211,107
1909	324,033	1924	263,044
1910	339,072	1925	191,011
1911	334,288	1926	169,824
1912	370,442	1927	210,406
1913	345,790	1928	189,312
1914	256,220		

Table 8.- Exports of Sulphur from Italy, 1924 to 1928, by Destination (Long Tons)

	1928	1927	1926	1925	1924
To Europe:					
Austria......	12,755	14,205	10,818	13,651	11,311
Belgium......	822	418	1,698	1,544	447
France.......	31,500	24,996	20,992	13,792	40,766
Germany......	6,397	5,765	6,629	10,025	11,955
Greece.......	14,810	15,661	8,270	17,169	6,149
Hungary......	1,238	1,344	678	666	485
Netherlands..	1,211	159	805	1,208	1,190
Portugal.....	7,358	2,155	1,968	13,894	10,701
Rumania......	1,887	1,824	1,571	862	1,362
Spain........	1,864	202	2,601	2,897	6,494
Sweden.......	7,779	3,822	10,240	5,140	16,580
Switzerland..	1,459	1,620	1,997	1,096	1,683
Turkey in Europe.....	405	391	316	219	562
United Kingdom.......	40,219	69,581	47,994	63,314	74,929
Yugoslavia...	2,256	2,988	3,564	2,101	1,958
To Africa:					
Algeria......	2,461	475	1,451	74	2,879
To Africa-Cont.					
British South Africa......	673	900	11,671	1,113	4,973
Egypt.........	1,726	1,708	1,568	1,188	1,566
Tunisia.......	1,135	826	703	1,548	911
To Asia:					
British India.	11,468	16,415	9,334	4,622	10,733
Netherlands East Indies.	8,376	18,622	7,330	11,197	5,931
Turkey in Asia	3,159	3,149	3,724	4,107	3,688
To South America					
Argentina.....	1,794	2,343	1,959	3,701	5,702
Brazil........	3,136	1,598	1,620	3,071	3,682
Uruguay.......	1,444	1,182	902	465	1,986
To Australia:					
Australia.....	480	625	588	459	16,208
Other countries.	21,500	17,432	13,704	11,888	18,222
Total	189,312	210,406	169,824	191,011	263,053

Table 9.- Exports of Sulphur from Japan (long tons)

Year	Quantity	Year	Quantity
1900	17,695	1915	74,279
1901	17,786	1916	82,031
1902	21,104	1917	84,768
1903	25,328	1918	53,668
1904	25,377	1919	28,441
1905	29,162	1920	19,530
1906	37,381	1921	
1907	31,137	1922	3,814
1908	30,289	1923	2,489
1909	41,082	1924	4,014
1910	44,884	1925	4,086
1911	36,773	1926	4,046
1912	48,726	1927	3,826
1913	53,825	1928	5,280
1914	51,159		

Table 10.- Exports of sulphur from Japan, 1923 to 1927, by destination (long tons)

Country	1927	1926	1925	1924	1923
China	1,959	2,557	2,015	1,753	866
Kwantung Province	416	320	437	679	240
Hong-kong	687	867	1,254	1,223	145
British India	174	97	113	148	184
Straits Settlements	46	37	240	120	88
Dutch India	510	152	3	50	—
Other countries	34	16	24	41	966
Total	3,826	4,046	4,086	4,014	2,489

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